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SUPPORT EQUIPMENT DEPLOYABILITY: A DELPHI STUDY TO DETERMINE THE TRANSPORTABILITY CHARACTERISTICS OF AEROSPACE GROUND EQUIPMENT (AGE)

THESIS

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Gavin B. Tovrea

Table of Contents

Page

Page

List of Figures

List of Tables

AFIT/GLM/LAL/97S-6

Abstract

The issue of mobility is vital to the Air Force as it faces the 21st century. Operational units must be prepared to quickly deploy anywhere in the world. Aerospace Ground Equipment (AGE) is a large portion of any operational unit's mobility requirements. The Multi-function Aircraft Support System (MASS) program proposes to reduce the amount of AGE required by operational units by combining the functions of many different pieces of AGE into new multi-function units. This thesis studies one portion of AGE mobility, the transportability characteristics of the Air Force's current powered AGE. Transportability is defined as the ability to quickly and efficiently prepare an item for transport, load the item on the transportation asset, remove the item from the transportation asset, and reconstitute the item for use. The results of this study provide a basis for judging the transportability of various MASS program options.

In order to determine AGE transportability characteristics, a Delphi study was conducted to solicit inputs from experts in the field. Study participants were three AGE technicians and three logistics planners from three fighter wings and two C-5 load masters and two KC-10 boom operators from three mobility wings. Factors that improved the transportability of AGE were the ability to be lifted by forklift, the ability to be rolled-on and rolled-off of transport aircraft, and high ground clearance. Factors that hindered mobility were large fuel capacities, large size (especially if pallet overhang occurred), heavy weight, and single axle designs.

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I. Introduction

With the fall of the former Soviet Union from super-power status the United States has the opportunity to completely reevaluate all aspects of the way its military performs its missions. With no likely major threat to our nation's existence foreseeable in the next several years, we must now analyze how the military has planned and conducted operations with an eye to getting the most capability out of every dollar we spend. This task becomes even more critical in the fiscal reality of the post cold-war federal budgets.

The first step in determining how to make the military more cost efficient is to specify the roles and missions of the military. With no individual nation to focus our efforts against, the military will likely be required to have the capability to deploy expeditionary forces of varying sizes to fight or deter regional conflicts, as is evidenced by the current Air Force Vision of Global Engagement. Such a military must be able to get to the right place at the right time, with the personnel, equipment, and supplies to fight or deter war. Pre-positioning the equipment necessary to fight the war is not feasible because of the fact that we cannot predict where the war will be. Even if pre-

positioning were possible, the US does not have close enough allies in all of the likely crisis regions to allow us to position the quantities of the equipment that we will need. Therefore, we must have a military that is strategically mobile. This military must be able to quickly move to the theater of operations, establish the military bases necessary to fight, develop the logistics functions to support the forces, and be able to conduct combat operations in as little time as possible. One way to improve our strategic mobility is to reduce the amount of support equipment Air Force units require to conduct operations.

Potential Ways to Reduce Support Equipment Requirements

There are two primary ways to reduce the amount of support equipment (SE) required by Air Force units. First, new aircraft designs can incorporate on-board equipment to fulfill the requirements for SE, especially the powered SE. For large aircraft (i.e. tanker, cargo and bomber aircraft) this is already the case. Large aircraft usually have an on-board auxiliary power unit which is capable of providing electrical power, air conditioning, and hydraulic power for use by aircraft systems during maintenance and launching operations. For smaller aircraft (i.e. fighter, attack, and trainer aircraft) this option is less satisfactory. As these systems are incorporated into the aircraft designs, the weight and size of the aircraft increase. This has adverse impacts on the performance of the aircraft, effectively decreasing the maneuverability, range, and ordnance load.

The second option is to reduce the size and weight of the existing SE, or combine the functions of SE into fewer pieces of equipment. For powered SE this would be possible by redesigning the equipment from the ground up and incorporating new

technologies, but the size of non-powered SE (maintenance stands) is usually dictated by the specific jobs for which the stands are intended. The Multi-function Aircraft Support System (MASS) program is an Air Force initiative to reduce the size and weight of support equipment.

The MASS Program

The MASS program sponsored by Armstrong Laboratories is aimed at producing a single piece of equipment that can provide electrical power, air conditioning, hydraulic systems, nitrogen servicing, lighting, and high and low power compressed air for flightline maintenance support. If the program is successful, the resulting piece of SE will fulfill the needs of all of the aircraft in the current and foreseeable future Air Force inventory. To enhance the maintainability of the MASS system, the program is now stressing the need for the system to be modular in design. The modular nature of the equipment will allow for line-replaceable units to be easily "swapped out" on the cart, allowing for two level maintenance support. The modular design also minimizes the amount of time the cart is out of service due to a single system being broken, and can even allow for the cart to be returned to service with partial capability if a replacement module for the broken system is not available.

Problem Statement

The purpose of this research is to determine the transportability problems of the current powered AGE used by the Air Force. Knowledge of the problems with the current AGE systems could be used during the early stages of design of the MASS

systems to avoid similar problems with the new equipment. This research will provide designers with information that will result in new support equipment with improved transportability characteristics.

The study will focus on four pieces of power support equipment currently in the Air Force inventory, the AM32A-60A (*dash 60*), the AM32C-10 (*dash 10*), the TTU-228 (*mule*), and the NF2-D (*LiteAll*). The rationale for this decision is that they are the largest pieces of powered AGE used (Gaumer: 7), they constitute the bulk of the powered AGE for required by fighter/attack aircraft (Battelle, September 1996: 12), and because they are likely to be the easily discernible to the participants of the study. (Participants may not be able to recognize the difference between a MC-1A and a MC-2A which would result in confusion. Such confusion could render the study useless.) The following research questions will be addressed:

1. What transportability problems exist in the Air Force's currently fielded powered AGE designs?

2. What improvements can be incorporated into the MASS program to improve the transportability of the MASS equipment?

3. What is the limiting factor in deployment of Air Force units, the weight of equipment, the volume of the equipment, or the amount of floor space of the cargo bay used?

Chapter II will summarize the pertinent literature reviewed in this study. This review covers three main topic areas: the current powered AGE inventory; mobility, deployability, and transportability studies and their findings; and the MASS program.

Chapter III describes the methodology of the study. The methodology used is the Delphi technique for soliciting the opinions and determining a consensus of experts. A panel of logistics planners, load masters, and AGE maintenance technicians will be asked to rate the transportability of the four pieces of powered AGE involved in the study and to raise issues about the transportability of those pieces of equipment.

Chapter IV provides the results of the Delphi study and Chapter V provides the conclusions of the research effort.

II. Literature Review

This Chapter summarizes the pertinent literature reviewed while preparing for this study. The first section examines the current Aerospace Ground Equipment (AGE) used by the Air Force, especially powered AGE. The second section examines several sources of information on mobility, deployability, and transportability. Finally, the third section covers the Multi-Function Aircraft Support Equipment (MASS) program.

Aerospace Ground Equipment

Aerospace Ground Equipment (AGE) consists of various pieces of specialized support equipment for performing maintenance and servicing tasks on aircraft. Unlike many other types of support equipment like test sets and specialized tools, AGE is not generally aircraft specific. A single piece of AGE is usually designed to meet the needs of several different aircraft.

AGE is functionally divided into two separate categories, powered and non-powered. Non-powered AGE consists primarily of maintenance stands, servicing carts, specialized trailers, and cranes. Maintenance stands are platforms to provide maintenance personnel access to aircraft components not accessible from the ground. Servicing carts are used to pump fluids into aircraft when needed. Examples of servicing carts are engine oil carts and hydraulic fluid carts. Specialized trailers provide for the movement and/or installation of various components on the aircraft. For example, one type of trailer may be used to move and ship an aircraft engine, while another trailer may be used to install the same engine on the aircraft. AGE cranes are used for the installation of items that are

not heavy enough to require a powered crane, but are bulky or hard to access like ejection seats or canopies. Cranes that are used for other purposes, like lifting an aircraft with collapsed landing gear off of a runway, or for the installation of thrust reversers on cargo/tanker aircraft are not generally considered AGE.

Powered AGE consists of equipment used to support maintenance efforts by providing external electrical power, cooling air, hydraulic pressure, external lighting, pressurized nitrogen or air, or "shop" electrical power. External power may be required to operate the electrical system of the aircraft. Cooling air may be required to keep electrical components from overheating while maintenance tasks are performed. Hydraulic pressure may be required to test the function of hydraulic components after maintenance has been performed on the hydraulic system. External lighting is required when performing maintenance at night. High pressure nitrogen and air may be required to service landing gear struts and hydraulic system accumulators. Low pressure air and "shop" electrical power may be required to power certain maintenance tools.

To provide these requirements, Air Force units require a large amount of equipment in order to perform routine maintenance functions. The following paragraphs list the major pieces of powered AGE in the Air Force inventory, along with a brief description of the function they serve and the physical characteristics of the equipment (size and weight). In all cases, dimensions are listed as length x width x height.

The AM32A-60A (commonly called the *dash 60*) is a small turbine engine which is used to generate electrical power for aircraft systems and provides pneumatic power to drive the AM32C-10 (Battelle, July 1996: 14). The *dash 60* is a very heavy piece of

equipment, weighing 3,120 lbs (Gaumer: 7). The external dimensions of the *dash 60* are 123" x 62" x 68" (Gaumer: 7). Based upon this information, the *dash 60* consumes a volume of at least 300.1 ft^3 and requires 53 ft^2 of floor space.

The AM32C-10 (commonly called the *dash 10*) air conditioner is used in conjunction with the AM32A-60A to provide cooling air to the aircraft's avionics components. While the *dash 60* provides electrical power directly to the aircraft's electrical system to power the avionics, it also provides pneumatic power to the *dash 10* which converts it into cooling air (Battelle, July 1996: 9). The *dash 10* weighs 1,380 lbs, and its dimensions are 108" x 71" x 69" (Gaumer: 7). The calculated volume and floor space required to ship the *dash 10* are 306.2 ft^3 and 53.25 ft^2.

The TTU-228 (commonly called the *mule*) is a hydraulic test stand which provides hydraulic pressure to the aircraft's hydraulic systems in place of the aircraft's own on-board hydraulic pumps (Battelle, July 1996: 13). Most aircraft hydraulic pumps are mounted on the engines, so in order to provide pressure to test hydraulic system maintenance either the engines must be started or a *mule* must be used. Larger aircraft may have hydraulic capability available from their auxiliary power units. The *mule* is the largest piece of common powered AGE found on the flightline, weighing 6,690 lbs. with external dimensions of 144" x 72" x 79" (Gaumer: 7). Thus the *mule* requires a minimum of 474 ft^3 worth of volume, or 72 ft^2 of floor space for shipment.

The NF2-D (commonly called the *LiteAll*) is used to provide external lighting during night time maintenance operations. In addition, it provides "shop" (120v AC) electrical power for operation of electrical tools and equipment (Battelle, July 1996: 8).

Although "shop" electrical power is not often required on the flightline, when it is the *LiteAll* is its only source. The NF2-D weighs 2,280 lbs. and has external dimensions of 108" x 68" x 67" (Gaumer: 7). Thus the *LiteAll* consumes 284.75 ft^3 of volume and 51 ft^2 of floor space during shipping. Because of its requirement to provide lights that can be positioned at varying heights, the cart has a wide wheel base and is heavy to prevent the unit from tipping over in high winds (which in operation still occasionally happens). Because of this requirement, the cart consumes a lot of volume and has a lot of dead weight. Inside the *LiteAll* there is a considerable amount of space that is not used. For this reason, the *LiteAll* could possibly be redesigned to incorporate a smaller piece of powered AGE on the same frame, which could replace some of the *LiteAll's* dead weight with usable weight, and could decrease the mobility requirements of deploying units by moving the same amount of AGE capability in the same volume or floor space.

The NSU-L75 liquid nitrogen cart (Battelle, September 1996: 9) (commonly called a *nite cart*) is used to convert liquid nitrogen into high pressure gaseous nitrogen for servicing hydraulic accumulators, landing gear struts, and to inflate tires (Battelle, July 1996: 11). The *nite cart* weighs 3,400 lbs. and is 126" x 60" x 55" in size (Gaumer: 7). During deployment it requires 206.25 ft^3 of volume and 52.5 ft^2 of floor space.

The MC-2A compressor (commonly called a *low pack*) provides low pressure compressed air for pneumatic tools (Battelle, July 1996: 12). The low pack weighs 880 lbs., is 87" x 47" x 40" in size (Gaumer: 7). The low pack requires 94.7 ft^3 of volume and 28.4 ft^2 of floor space during shipment.

The MC-1A compressor (commonly called a *high pack*) provides high pressure air to service hydraulic accumulators, landing gear struts, and inflate tires (Battelle, July 1996: 16). The high pack is used for functions similar to the gaseous nitrogen cart. The differences between the uses of the two units are generally aircraft and subsystem specific. For example, some hydraulic systems require accumulator servicing with nitrogen, while others require only compressed air. The *high pack* weighs 1,980 lbs. and is 88" x 67" x 60" in size (Gaumer: 7). During shipment, the high pack requires 204.8 ft^3 of volume and 41 ft^2 of floor space.

The AM32A-86D (commonly called a *dash 86*) provides external electrical power for aircraft electrical systems. Since the *dash 86* provides only part of the capability of a *dash 60* with approximately the same space and weight, the *dash 86* is not commonly deployed (Battelle, July 1996: 15). The primary reason for the *dash 86's* existence is that it can provide equal electrical generation capacity to the dash 60 while consuming much less fuel.

The powered AGE requirements for a deploying unit vary widely depending upon the type and number of aircraft to be deployed. The powered AGE requirements for an F-16 unit of 18 aircraft are listed in Table 1.

Table 1. Powered AGE requirements for F-16 squadron (18 aircraft)

AGE type	Quantity
AM32A-60A	10
AM32C-10	9
MC-1A	1
MC-2A	4
TTU-228	2
NF2-D	9

(Department of the Air Force, "3FKM3 UTC," 1995)

Strategic Mobility and the Air Force

Air forces by their nature tend to be very logistics intensive, requiring extensive support in the form of maintenance technicians, support equipment (SE), and spare parts. Getting the aircraft to the theater of operations can be accomplished relatively quickly, but getting their logistics resources there requires a tremendous effort. Even when the logistics resources can be made available, the rapid rate of consumption for fuel and munitions by air forces complicates the situation even further. The amount of resources required to support an Air Force unit is referred to as the unit's "mobility footprint." The larger the mobility footprint, the more mobility resources will be required to move the unit to the theater of operations.

Mobility Resources

Mobility resources consist of airlift and sea-lift assets. These assets differ significantly in their characteristics, airlift assets providing rapid deployment with limited capacity, while sea-lift assets provide large capacity with limited speed. Airlift assets are expensive to maintain due to their large logistic requirements and the continuous need to provide training for aircrew and maintenance personnel in both peace and wartime. Sea-lift forces on the other hand can be maintained with relatively little cost.

The Global Engagement doctrine and its vision of rapid deployment dictates that units of the Air Force which deploy to meet regional crises arrive quickly and with the ability to conduct nearly immediate combat operations. This requirement eliminates the possibility of using sea-lift assets to move the required logistics resources to the theater of operations. The resulting reliance on airlift necessitates the minimization of the mobility

footprint of air force units because of the high cost to maintain the required airlift requirement during peace time, and because of the scarcity of airlift assets during crisis. Minimization of the mobility footprint provides both the minimum cost during peace (through lower costs to maintain a smaller airlift force) and maximum deployment of combat forces during a crisis (fewer assets required to deploy each combat unit).

Mobility Characteristics of Air Force Units

The mobility requirements for Air Force units are outlined in Unit Type Codes (UTCs). These codes specify the amount and types of personnel, equipment, and spare parts with which a unit is authorized to deploy based upon the number and type of aircraft being deployed (Zeck, Lloyd, & Pool, 1995: 25). In effect, the UTC determines the unit's mobility footprint, which is typically defined in terms of pallet positions required. The metric of pallet positions required is based upon the belief that most airlift aircraft do not run out of maximum weight or cubic volume before they run out of square feet of floor space when carrying cargo. As an example, a UTC for an F-16 C/D squadron with 18 aircraft includes 202.5 pallet positions of cargo and 413 people (Gaumer, 1995: 7-11) and of this, nearly 70% is support equipment (Gaumer, 1995: 5). This equipment consists of powered and non-powered SE, and miscellaneous flightline equipment (i.e. tools). Powered SE consists primarily of 32A-60A power carts (-60s), C-10 air conditioners, MJ-2A hydraulic test stands (mules), high and low pressure air compressors, NF-2 Lighting carts (LiteAlls), and liquid nitrogen carts. Non-powered SE mainly consists of maintenance stands.

The Importance of Mobility

The end of the cold war created new challenges for the military branches of the United States. Instead of a strong central threat to our national security, the post cold-war world contains innumerable minor threats to our national interests. In response to this fundamental change, the Air Force developed a vision document entitled *Global Engagement*. This document identifies six core competencies that the Air Force possesses and intends to continue to develop in order to meet the challenges of this less structured environment (Department of the Air Force, "Global Engagement"). The six core competencies identified are: Air and Space Superiority, Global Attack, Rapid Global Mobility, Precision Engagement, Information Superiority, and Agile Combat Support (Department of the Air Force, "Global Engagement").

Two of these core competencies, Rapid Global Mobility and Agile Combat Support, deal directly with the future of Air Force Mobility. "Rapid Global Mobility provides the nation its global reach and underpins its role as a global power. The ability to move rapidly to any spot on the globe ensures that . . . the nation can respond quickly and decisively to unexpected challenges to its interests" (Department of the Air Force, "Rapid Global Mobility"). In addition, the Rapid Global Mobility concept calls for utilizing fewer combat aircraft by employing precision weapons, thereby decreasing the footprint of "tailored [air combat] forces" (Department of the Air Force, "Rapid Global Mobility").

Agile Combat Support calls for "Effective combat support operations [which] allow combat commanders to improve the responsiveness, deployability, and

sustainability of their forces" (Department of the Air Force, "Agile Combat Support"). This improvement would involve the deployment of fewer spares and consumable supplies with the unit in its initial deployment, instead relying on reach-back to provide the replenishment required from the first day of the operation (Department of the Air Force, "Agile Combat Support"). This reach-back policy would initially involve less air lift to get a unit into the theater of operations, but would require immediate availability of bulk cargo capability. This immediately improves the air lift requirements picture, since less of the specialized Air Force cargo aircraft capability would be used to deploy spares and supplies. Instead, this bulk cargo could be delivered by mobilized Civil Reserve Air Fleet (CRAF) assets which have little or no capability to haul large equipment. Since the former mobility policy usually called for a unit to deploy with spares and supplies to initially sustain itself for 30 days of operation, the resulting reduction in initial air lift requirements could be substantial.

Background of Mobility in the Department of Defense

The Air Force's far reaching *Global Engagement* vision statement goes a long way towards solving a long standing problem in the Department of Defense. "One of the embarrassing issues within the Department of Defense is the failure to relate the size of the force to be moved with the strategic lift availability" (Perkins, 1984: 43). In the '80s, the military strategy of the United States consisted of forward basing forces and pre-positioning equipment to fight in Western Europe, Southwest Asia, and the Pacific region.

This strategy, with limited locations of potential crisis, allowed for large amounts of equipment to be stored in the area of expected crisis. This equipment could be "married-up" with troops deploying into the area (Perkins, 1984: 15-26). In this manner, significant combat power could be built within a matter of hours of the start of the crisis by using nearly any type of airframe to haul personnel into the area. This strategy was well supported by the combination of CRAF and Air Force assets, the CRAF could efficiently deliver the personnel, and the Air Force assets could begin delivery of additional equipment to further the force build-up. The major aim of this strategy was to improve our military credibility in these regions, and therefore deter Soviet encroachment into these regions (Perkins, 1984: 4-8).

During this period, the Air Force still was interested in the development of the capability to deploy into areas without pre-positioned equipment. In 1980 deployment to a "bare base" environment was proven in Exercise Proud Phantom in Egypt, but only with great difficulty. In the first phase of the exercise alone, 5 C-141s and 28 C-5s delivered the 4 million pounds of equipment and 450 personnel required. This effort resulted in the eventual deployment of merely 12 F-4E aircraft (Sowell, 1982: 18). Since this was not the likely scenario for the Department of Defense, this type of deployment did not receive as much attention as the Western Europe/Southwest Asia/Pacific Region scenarios.

With the fall of the Soviet Union, the Department of Defense's strategy of preparing for a war in a predictable region is much less appropriate. The Soviet threat was largely predictable, which allowed for detailed planning. Such planning allowed for

us to place forces in good operating locations to deal with the threat. Now that non-predictable threats abound, intra-theater airlift is much more important. Less precisely identified threats will result in "a decreased likelihood of initially placing combat forces in the best locations within a theater" (Cummins, 1992: 20). Not only do we need to reduce the mobility footprint of our units in order to efficiently get them into the area of operations, we must keep that footprint small in order to maintain the ability to shift forces as required within the area of operations.

Maximizing Effectiveness of Air Mobility Assets

Most studies dealing with mobility deal with the maximization of combat power delivered to the theater of operations in a given amount of time. Because of the distances covered and the lack of forward garrisoned bases in the area, deployment of forces to Southwest Asia to the Joint Central Command (CENTCOM) was usually used as a "worst case" scenario. Typical of mobility studies in the '80s, Tate states, "This problem is broken into two subordinate and equally important goals: maximize the combat power delivered, and minimize the delivery time" (Tate, 1984: 1-5).

What is the Limiting Factor of Air Mobility?

Most of these studies have dealt with the weight of equipment being deployed as the limiting factor, though it is not at all clear whether this is the case. Other limiting factors could be the volume available on cargo aircraft, or more likely, the floor space available in the cargo bay. Floor space may be further limited by "pallet positions" available, referring to the number of 463L pallets that can be loaded on an aircraft. Most

studies have concentrated on optimization of unit weight, combat attributes, logistics needs, and aircraft resources (Tate, 1984: 1-1).

Joint Staff mobility studies have focused on many different aspects of trade-offs when attempting to solve various problems related to air mobility, or to mobility in general (Schank, et al, 1994: 3). Typical transportation studies involve manipulating information about cargo, transportation networks, and transportation assets (Schank, et al, 1994: 1). The types of studies conducted by the Joint Staff included (1) studies to examine the structure of air mobility forces to analyze future mobility structure combinations; (2) to plan the operations of air mobility assets with a focus on routing and scheduling, which results in a feasible delivery profile given specific parameters; and (3) to examine broader trade-offs focusing on transportation assets considering cargo availability dates, needed-in-theater dates, and pre-positioning options (Schank, et al, 1994: 1-3). In these studies, the cargo required by a unit was seen to be fixed and unchangeable. Reducing the amount of cargo or the characteristics of the cargo was not mentioned (Schank, et al, 1994: 7-28).

The emphasis on mobility requirements in terms of weight is evidenced in a 1987 Congressional Budget Office report which identified that the established goal for air lift capacity was 66 million-ton-miles (MTM) per day (CBO, 1987: 3). In order to achieve this goal two major plans were considered, both of which involved only the purchase of additional aircraft (CBO, 1987: 1-28). One additional alternative plan called for reducing the air lift requirement, but this plan was a trade-off to provide less combat capability, not an initiative to reduce cargo requirements (CBO, 1987: 29-33). Even

today, studies and plans continue to focus on and emphasize the amount of lift required to move current equipment and cargo rather than on options to reduce the amount of, the size of, or changing the characteristics of the equipment and cargo itself (CBO, 1997: xvi-xxii).

During development of new weapon systems and equipment, mobility limitations are considered, but to what extent are they important? The ". . . DoD devotes considerable attention and resources to the transportability issue as it arises during the development process for material and equipment" (Zycher and Morton, 1991: 1). Although this statement may be true, Zycher and Morton subsequently show that these considerations are still not given top priority, and are primarily only considerations of maximum unit weight. Even when a weight requirement for a new weapon system is established, it often increases during the systems development. The M-1 Abrams tank increased in weight during design because of combat effectiveness issues (Zycher and Morton, 1991: 12). Was the weight of the vehicle really a design priority? Of the 11 parameters listed in order of priority on the Mission Ned Engineering Development document, transportability was listed 10th. The validation contract for the M-1 tank listed 16 priorities which did not include transportability at all (Zycher and Morton,1991: 12).

Why is weight used as the standard of measure for air mobility? It is an easy characteristic to measure. Although weight may not be the limiting factor, it is easy to determine the weight of each piece of equipment. These weights can then be simply summed to determine a total lift requirement. Even though many people do not think that weight is the limiting factor, there seem to be no studies to test that hypothesis. Different

studies make broad sweeping statements without providing any support for these statements. "Airlift weight is not addressed . . . because weight is not currently the limiting factor" (Battelle, September 1996: 11).

One excellent source on transportability involves an in-depth discussion of factors other than weight that determine the transportability of items. It addresses the internal loading characteristics of existing cargo aircraft by determining geometrical and structural constraints. Even though this gives major consideration to factors other than simply the weight of a piece of equipment, it still only addresses the ability of the equipment to be loaded on the aircraft and not the efficient use of the cargo space on the transporting aircraft. The considerations discussed included the approach and departure angles of the loading ramps, the clearance of specific points of the vehicle as it is loaded, and the vertical and horizontal door clearance of the aircraft (Department of the Army, 1984).

None of these studies really considers the possibility of improving the utilization of air mobility assets by reducing the size, weight, or quantity of equipment to be moved. The focus of an entire RAND study completed in 1996 was to maximize the force capability for the amount of equipment and supplies deployed, yet it did not address the fact that decreasing the amount of equipment and supplies required to achieve a given combat capability would in fact have the same effect (Kassing, et al, 1996). It seems that no one believes that such a possibility exists. It is more common to find studies that champion trading-off combat potential to improve mobility. "Thus, the military is faced with a common trade-off: how much combat potential should be foregone as a means of

increasing the ease or speed – or reducing the cost – of deployment?" (Zycher and Morton, 1991: 1).

Yet, most of the powered Aerospace Ground Equipment currently being used by the Air Force was designed in the 1950s and early 1960s. Redesign and acquisition of new equipment could do a lot to enhance the combat potential of the Air Force. Such a redesign could significantly reduce the size, weight, and quantity of equipment required to support a given number of aircraft. Such a reduction in size, weight, and quantity of equipment would directly result in more combat capability deployed to any theater of operations on the globe for a given amount of air lift, or the same amount of combat capability delivered with reduced airlift. "Constraints upon airlift will always exist, but the size of the deploying package of the future is being affected by the systems acquired today. Reducing the size of future deployment footprints today is one key to force projection in the new world order" (Griffis and Martin, 1996: 6).

How can the mobility of the Air Force be imroved and thereby achieve Rapid Global Mobility as identified in the Air Force *Global Engagement* vision statement? Look at the basic building blocks of unit mobility. "Very little attention is given to the building block of the process, the size of the package to be moved, which is generally treated as unchangeable in current systems" (Griffis and Martin, 1996: 9).

One major portion of the mobility package for any Air Force squadron is the AGE it requires. The potential exists for significant deployment package reduction if the quantity, size, and/or weight of the current equipment could be reduced. One way to do this is to develop a Multifunction Aircraft Support System (MASS). In such a system,

the functions of various pieces of powered AGE currently in the inventory would be combined into one or at most a few pieces of equipment with considerable reduction in total size and weight.

The MASS Program

Does the Air Force need multi-function SE? According to the Air Mobility Master Plan produced by Air Mobility Command (AMC), development of multifunction SE that is easy to maintain and that does not require frequent man-hour intensive inspections is one of the top priorities for AMC. The "determining factors for acquisition" will be weight, size, capabilities, ease of use, and cost (AMMP, 1997: 5-69). This view is apparently shared by Air Combat Command (ACC). ACC has developed a draft of a mission need statement which calls for integrated, modularized support equipment (Department of the Air Force, October 1996: 11-12).

With the incorporation of new technologies, the MASS program expects to produce a single unit with the capability to provide electrical power, air conditioning, hydraulic power, high and low pressure air, external lighting, and nitrogen generation in a single trailer about the size of the current 32A-60A power cart, and weighing about the same as the 32A-60A and C-10 air conditioner combined (Boyle & Tracy, 1995: 28). The combined weight of these two pieces of support equipment is 4,500 pounds (Gaumer, 1996: 7).

The modular nature of the MASS equipment will further improve outlook for deployability. With the current vision of the Air Force involving "reach-back" support for deployed units from the first day (Department of the Air Force, "Agile Combat

Support"), replacement modules could be sent into the area of operations as required, eliminating the need for numerous spare modules to deploy in the initial deployment package. The modular equipment would further reduce the deployment package by reducing the considerable AGE support elements currently deployed to support operational units to smaller elements required to remove and replace modules on the MASS trailers. These reduced AGE elements would also require much less equipment to perform their duties. "The fact remains that demand for airlift support will always exceed the capacity of the airlift forces. As a result, apportionment and effective use based on priority of need is a basic function of the air mobility system" (Joint Pub 3-17, 1995: vii). MASS would provide for more effective use of precious air mobility assets.

Likely Technologies for MASS

The MASS program is aggressively pursuing various technologies to provide the required support equipment capabilities. It is anticipated that these technologies allow for the development of service modules to provide each of the basic powered SE functions of electrical power generation, high volume air conditioning, hydraulic power, high and low pressure compressed air, nitrogen generation, and lighting. These service modules will be located on a trailer which will include a power source. Most likely, this power source will also be modular.

Currently, the program is focused on two basic configuration options, a system with an Internal Combustion Engine (ICE) power plant with a mechanical linkage to the service modules (called the mechanical bus option), and a system with a fuel cell electrical power plant or an ICE power plant with electrical bus power to the service

modules (called the electrical bus option). For the mechanical bus option the program office is exploring the potential use of a power plant that is currently in use by the US Navy for propulsion in its torpedoes. Reportedly, this power plant (including a small transmission to gear down the output RPMs) is small enough to be easily handled by a single person (making it ideal for the modular power plant concept) and is capable of operating a turbine at 10,000 rpm and producing 1,000 horse power. The Navy claims that even with repeated firing of its training torpedoes, they have a very high time between failure. The biggest drawback to this power plant is the fact that it currently uses a lithium based fuel. Other technologies being considered for the power plant include a simple lightweight diesel engine, more efficient gas turbine engines, and rotary diesel engines. (Pavek)

Another cutting edge technology being considered for the program is the potential use of Acoustic Refrigeration. The method of operation in an acoustic refrigerator is explained very thoroughly by Susalla (1988). Basically, acoustic refrigeration operates by passing energy over a plate which is surrounded by a gas to transmit heat from one end of the plate to the other. This is accomplished by repeating a cycle of six steps (see Illustration 1). The cycle is repeated at the rate of the frequency of the input energy.

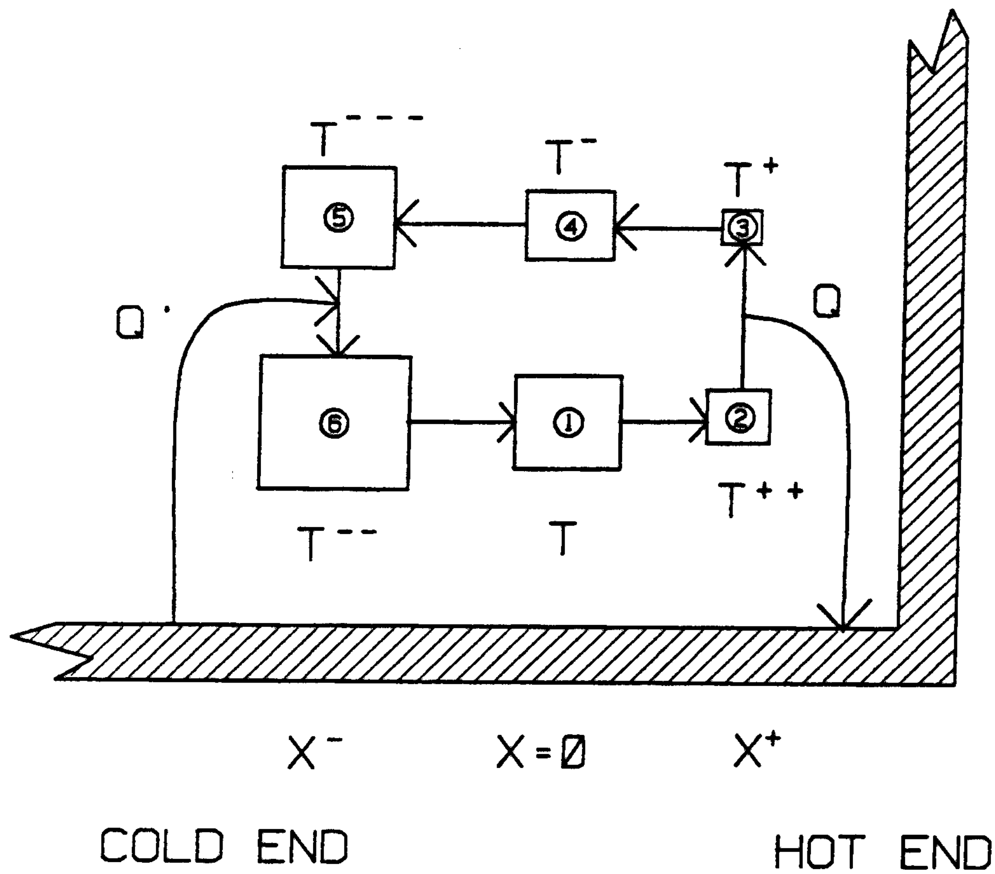

Figure 1. Principles of Acoustic Refrigeration
(Susalla, 1988: 22)

In the first step, a parcel of gas in position 1 is compressed by the sound wave and moved to the right to position 2. The compression has increased its temperature, which is higher than the plate (T^{++}). Since the temperature of the gas is higher than the plate, it transmits some of its heat to the plate, reducing it to a temperature of T^{+} represented by position 3 (position 3 is actually the same as position 2, the parcel has been moved up on the diagram for clarity only. The same is true for positions 1 and 4 and for positions 5 and 6). This transmission of heat caused the plate at position X+ to increase in temperature. The parcel is now moved by the returning sound wave to position 4 and expands, cooling

its temperature to T^{-}, and then to position 5 where its temperature has now dropped to T^{--}. The temperature of the gas is now lower than the plate at position X^{-}, so heat is transmitted from the plate to the gas cooling the plate at position X^{-}. The particle is then moved by the sound wave to position 1 where the cycle restarts (Susalla, 1988: 21-23). "Notice that the temperature of the gas parcel at position X=0 is different depending on which direction the gas parcel is moving. It is this phase shift in temperature relative to motion that produces the thermoacoustic effect, . . ." (Susalla, 1988: 23).

When a chain of these gas parcels a placed together, the effects on any point along the plate are nullified, but at the ends the effect builds up, creating a heated and a cooled end of the plate (Susalla, 1988: 24). When a large number of these plates are combined a cumulative effect can be created increasing the capacity of the refrigerator to meet the needs of your system.

Obviously this technology may be able to be adapted to provide the basic function for the air conditioning module on the cart. In addition the designers are looking into using this technology for electrical generation. If instead of inputting a frequency you chose to input heat to one side of the filter, you may be able to generate both the cooling effect and an output frequency. This output frequency may then be able to be harnessed and used to generate electrical power.

Limitations of Existing Literature

Although many sources discuss the issue of mobility, and they have many definitions for the terms mobility, deployability, and transportability, none of them really discuss the issues that this study plans to cover. According to Battelle, deployability is

"A measure of the resources required to transport, set up, and operate a system in a remote location, quantitatively measured in linear time and man-hours necessary for deployment preparation and recovery, also measured in terms of the volume, weight, and packaging requirements of the material to be deployed" (Battelle, July 1996: 3). This definition is the most closely related to issues proposed for this study. Another definition that is closely related to my study is provided by Zycher and Morton, "Increasing the speed of deployment, or reducing its cost, is termed . . . 'transportability'" (Zycher and Morton, 1991: 1).

Transportability is defined for the purposes of this study as the ability to quickly and efficiently prepare an item for transport, load the item on the transportation asset, remove the item from the transportation asset, and reconstitute the item for use. Thus, improvements in transportability could involve decreasing the time required to accomplish any of those tasks, or decreasing the amount of people or resources required to accomplish any of those tasks, or both.

> Equipment that is not transportable to the area of operations when needed has zero effectivity. . . . However, often times has been true [sic] that items receive very little consideration as far as transportability during their design, and this renders the item to an effectivity of zero regardless of how well it will perform once arriving at its environment. If you can't get it there, its of no use. (Department of the Army, 1984)

III. Methodology

The objective of this chapter is to explain the general methodology used in this study, to explain the choice of the methodology including the strengths and weaknesses of the method, and to outline the research plan.

The Delphi Method

For this study, the Delphi method was selected to gather expert opinions about the transportability of the U.S. Air Force's current Aerospace Ground Equipment (AGE). This technique was selected primarily because of the lack of existing quantifiable data on the subject. It was therefore appropriate to conduct a study based upon the opinions of people who have expertise in the subject in order to form a basis for further research into this topic and related topics.

The Delphi method was developed by the RAND corporation in the 1960s for the systematic solicitation, collection, evaluation and tabulation of the independent opinion of experts without using group discussion (Tersine and Riggs, 1976: 51). The objective of the technique is to "... obtain a group response of a panel of experts ..." which is based on and emphasizes their informed judgment (Brown, 1968: 3). The method basically involves the anonymous collection of opinions from members via a series of questionnaires. The results of these questionnaires are then tabulated and returned to the group members for feedback, and then the members again give their revised answers to the question. The process continues until a stopping condition is reached, either a consensus is reached or convergence on a consensus ceases (Dalkey, 1967: 3-5).

It is important to note that the Delphi technique does not result in an "exact" answer to a question. The Delphi process is useful to improve the utilization of expertise in studies, which is why it is often used in the field of operations research.

> The objective of operations research is not so much to find things out – as the pure scientist tries to do – but to help arrive at efficient operating decisions. This pragmatic attitude implies that the operations analyst, in dealing with phenomena for which no well-established scientific theory is currently available, must nevertheless construct a model as best he can, using whatever intuitive insight limited practical experience may have yielded in order to choose the appropriate structure for the model and to estimate appropriate values for the input parameters. (Brown and Helmer, 1964: 1-2)

The effectiveness of the Delphi technique to arrive at a useful answer to a question depends to a large extent upon the design of the study and the actual expertise possessed by the panel members. Though it does lack the ability of finding a "true" answer, the technique is useful in finding an agreed upon consensus about the nature of the "true" answer. "For material where confirmation is possible, typical outcomes are that opinions tend to converge during the experiment, and more frequently than not, the median response moves in the direction of the true answer" (Dalkey, 1967: 4).

The Delphi Process

The general method for conducting a Delphi experiment is a four step process (commonly called rounds). In the first step, each group member is asked the question, and is asked to assign a competence level to his ability to successfully answer the question. In the second step, each member is again asked the question and is asked to provide reasons for the answer. In the third round, each member is given a synopsis of the responses and is asked to critique the responses and is given the opportunity to revise

their response to the question. In the fourth round, the members are asked to provide counter arguments, and again revise their response to the question (Brown, 1968: 4-6).

Advantages of Delphi

Because of the way a Delphi study is conducted it has several advantages over other methods for achieving a group consensus. These advantages stem primarily from the lack of personal interaction between members. Since the anonymity of the panel members is maintained personality difference impact is reduced. "Individual input integrity is preserved without potential intimidation or idea degeneration" (Anderson, 1990: 9-10). Another advantage of the anonymous nature of the study is that it is easier for a participant to change his or her position on a subject since that person does not feel obligated to defend a previous position. There is less ego involvement when that person does not have to admit that he was wrong before (Tersine and Riggs, 1976: 51).

Another major advantage to the Delphi technique which comes from the anonymity of the process is the reduction of a "halo" effect caused by the perceptions of colleagues as experts in a subject area (Tersine and Riggs, 1976: 51). The opinions of a well respected person hold more weight with a group than the opinions of a less respected person, whether or not those opinions are fundamentally valid.

In additions to reducing the "halo" effects within a group, the Delphi method also eliminates the problems of dominant personalities in group decision making. Since group membership is anonymous and there are no meetings, confrontation is limited to constructive dialog between potentially opposing ideas (Tersine and Riggs, 1976: 52).

Also, any conflicts that do arise can be mediated by the researcher to prevent or reduce hostile comments or reactions.

Overall, the fact that the Delphi process is anonymous and not subject to normal group dynamics usually results in a "greater flow of ideas, fuller participation and increased evidence of problem closure" (Tersine and Riggs, 1976: 51).

Another major advantage to the Delphi technique, and one which was important in its consideration for this study, is the fact that it is easier logistically to perform. Since there are no common meetings required of panel members, each individual member can participate in the study by completing their questionnaires at their convenience.

Disadvantages of Delphi

The disadvantages of the Delphi method are also worth pointing out. The first and most important disadvantage is that it depends entirely upon the quality of the expertise possessed by the panel members. This makes the selection of panel members important to the success of the study (Tersine and Riggs, 1976: 55).

The second major disadvantage to the Delphi process is, due to its iterative nature, it requires more time to complete than other forms of group decision making (Anderson, 1990: 10). Therefore, panel members must be committed and motivated to being part of the study to the end which could last for months. If the study cannot achieve results (or at least observable movement towards results) quickly, panel motivation can wane (Tersine and Riggs, 1976: 55).

Research Plan

For this study, a Delphi method was used with one major modification. One step was added to the process to identify specific characteristics of the various types of AGE that cause mobility problems. This step was necessary because no information was available to determine what specific characteristics of the existing AGE cause problems in the area of transportability. Once this step (which is refered to as Round 0, or the Preliminary Round) was completed a Delphi study was conducted to determine which of the characteristics identified in Round 0 were the most serious problems.

The research conducted was broken into three areas, the problems in preparing the Air Force's current Aerospace Ground Equipment (AGE) for deployment, the problems planning and loading that same AGE for deployment, and the limitations of Air Force cargo aircraft. For the first research area, 4 AGE technicians were included in the Delphi process because they perform the actions required to prepare the AGE for shipment. The four AGE technicians were from four different Air Force bases, each of which operated fighter/attack type aircraft. The bases originally selected to provide AGE technicians for participation in the study were Cannon AFB, NM; Mountain Home AFB, ID; Pope AFB, NC; and Seymour Johnson AFB, NC. After contacting Mountain Home AFB, however, the wing leadership declined to participate due to operations tempo problems. The replacement base selected was Moody AFB, GA. The aircraft operated by these participant bases included F-15Es, F-16C/Ds, and A-10s. These aircraft types were studied because they are the most likely aircraft types to be deployed as part of an air

expeditionary force, which is the most likely mobility contingency operation in the near future.

For the second research area, 4 logistics planners and 4 cargo aircraft load masters were included since they are responsible for developing aircraft load plans and actually loading the AGE onto aircraft during deployments. The logistics planners were selected from the same operating bases as the AGE technicians above for the same reasons. The load masters were selected from KC-10A aircraft (load master duties are actually performed by the aerial-refueling boom operator) and the C-5B aircraft. The study originally intended to include C-141B load masters but deployment schedules prevented their inclusion in the study. Participants were selected from the following bases, McGuire AFB, NJ; Dover AFB, DE; and Travis AFB, CA. McGuire AFB provided one KC-10A boom operator for the study, Dover AFB provided one C-5B load master, and Travis AFB provide one of each for the study.

The third area of study, the limitations of Air Force cargo aircraft, is really an attempt to answer a basic mobility question. This question is "What is the real limitation for cargo aircraft, weight, volume or area?" To answer this question, the logistics planners and load masters were asked to provide data on how often an aircraft that was considered "full" ran out of available cargo weight, available volume inside the aircraft, and available floor space. This question was not subjected to the Delphi process to converge on a consensus, but was asked only to try to gather basic information about the actual operational limitations of the Air Force's current cargo aircraft.

Since the MASS program intends to replace only powered AGE systems, this study's scope was limited to only powered AGE. The specific powered AGE systems studied included the following:

Table 2. AGE Studied

Designation	Common Name	Function
AM32A-60A	"dash 60"	Aircraft electrical power, high volume pneumatic power for "dash 10"
AM32C-10	"dash 10"	Air Conditioner
TTU 228	"mule"	Hydraulic test stand
NF2-D	"light all"	Perimeter lighting and 110V electrical power.

The above types were selected because they tend to be the largest portion of a deploying fighter unit's powered AGE, and because they are easily distinguishable from each other. Other types of powered AGE includes liquid nitrogen carts, MC-1A *high pack* air pressure carts, and MC-2A *low pack* air pressure carts. These were not studied because they tend to be included in deployment packages in smaller numbers than the AGE studied, and because there was concern that they might be mistaken for other types of AGE and therefore might cause problems with the results. For example, we were concerned that participants might mistake a liquid nitrogen cart for a gaseous nitrogen cart, which has significantly different physical characteristics and therefore potentially different transportability characteristics. In a similar vane, there was concern that the *high pack* and *low pack* air pressure carts might be mistaken for each other and therefore they were also excluded from the study.

Selection of Experts

Experts were selected from the above mentioned bases based upon nominations from the bases' leadership. Selection criteria provided to the bases included actual on hand experience in deploying or preparing to deploy AGE for either "real world" taskings, exercise deployments, or exercise deployment simulations.

Table 3. Demographics of Experts

Participant	Rank	Notes
Cannon AGE Technician	SrA	
Moody AGE Technician	MSgt	
Pope AGE Technician	MSgt	
Seymour Johnson AGE Technicain	TSgt	Removed from study due to leave
McGuire Boom Operator	SMsgt	
Travis Boom Operator	MSgt	
Dover Load Master	MSgt	
Travis Load Master	MSgt	
Cannon Logistics Planner	Capt	
Moody Logistics Planner	GS-9	
Pope Logistics Planner	SMSgt	
Seymour Johnson Logistics Planner	TSgt	Removed from study due to lack of expertise

Preliminary Round

During the preliminary round, each participant was sent, via e-mail, a questionnaire. The questionnaire for AGE technicians asked, "How difficult is the AM32A-60A (*dash 60*) to prepare for deployment?" and "How difficult is the *dash 60* to reconstitute after deployment?" with a response scale of 1 (extremely difficult) to 5 (extremely easy) to prepare. The respondent was also asked to grade his area of expertise in preparing the AM32A-60A for deployment from 1 (not well qualified to judge) to 5 (have performed the actions many times). The respondent was then asked to provide

specific characteristics of the equipment that make it hard to prepare for deployment or that greatly improves the ability of the equipment to be prepared for deployment. The questionnaire also included the above portions for all four of the equipment items included in the study.

The questionnaire for the logistics planners and load masters asked, "How difficult is the AM32A-60A (*dash 60*) to incorporate in load plans?" with a response scale of 1 (extremely difficult) to 5 (extremely easy). The questionnaire for logistics planners also asked "How difficult is the *dash 60* to martial between cargo holding points?" and the questionnaire for load masters asked "How difficult is the *dash 60* to load onto aircraft?" with the same response scale. In addition, the respondent was also asked to grade his area of expertise in load planning and loading the AM32A-60A for deployment from 1 (not well qualified to judge) to 5 (have performed the actions many times). The respondent was then asked to provide specific characteristics of the equipment that makes it hard to prepare for deployment or that greatly improves the ability of the equipment to be prepared for deployment. The questionnaire included the above portions for all four of the equipment items included in the study.

The questionnaires for the logistics planners and load masters also asked "In your experience, when an aircraft is considered 'fully loaded' with cargo, what percentage of the time has the aircraft been limited by: (a) aircraft floor space/pallet positions, (b) aircraft volume (cube), or (c) aircraft maximum weight?"

There were numerous problems encountered during the preliminary round. The first problem was that the e-mail systems of some participants did not allow reliable

transmission of questionnaires and responses. As a result, one of the AGE technicians responded via FAX, as did one of the boom operators. For these individuals all following round questionnaires were distributed by FAX. Another problem encountered was one of the AGE technician participants had gone on long-term leave a few days before the study began. This individual was removed from the study, leaving 3 AGE technicians to participate. The only other problem was the logistics planner who indicated that she lacked the expertise to participate in the study. As mentioned above, she was removed from the study.

Round 1

During Round 1, the questionnaire repeated the questions asked in the Preliminary Round, with the exception that the questions concerning the expertise of the participant were not repeated. In addition to the previous questions, the Round 1 questionnaire included questions developed from the open questions about specific transportability characteristics of each type of AGE identified in round zero. These questions were generally scored on a scale from 1 (significantly degrades transportability) to 5 (significantly improves transportability). As much a possible, when a participants preliminary round response identifying a characteristic tended to naturally lead to a positive or negative conclusion about the transportability affect, the question developed attempted to remove the positive or negative connotation of the characteristic. For example, if a participant indicated that "the high ground clearance of the *dash 60* improves its transportability," the question developed would ask, "What effect does the ground clearance of the *dash 60* have on its transportability?"

Though not originally intended to be repeated on all questionnaires, the question about aircraft cargo loading limitations was repeated in Round 1 because there was a general disagreement between the experiences of load masters and logistics planners.

The only problem encountered in round one was that the logistics planner and AGE technician participants at one of the participating bases found each other and worked together on their questionnaires. Although this at first would seem to cause a problem with the integrity of data, the fact that each participant is in a separate group keeps this from being a major problem. The goal of the Delphi study is to gather the opinions of experts. Expertise is not only knowing everything about a subject, but also knowing when your knowledge is limited. And when an expert lacks the knowledge he looks to other sources to augment his knowledge. Therefore, experts not only have their own knowledge but also have the experience and connections to tap the knowledge of others when they lack knowledge. With this in mind, it is not surprising that two of the experts in the study found each other while answering their questionnaires.

The major problem arose when both of these participants returned the questionnaire for the AGE technician. When this happened, the logistics planner was contacted and resent the logistics planner questions to which he responded. The AGE technician questions he submitted were removed from the study. It is interesting to note that the two copies of the AGE technician questions did not have identical answers, a further indication that even with the cross flow of information between the participants they still were willing to submit their own answers.

Round 2

The questionnaire for Round 2 was the same as the Round 1 questionnaire, but it included the range of scores from the previous round. The second round also asked for justification to support the expert's response.

The biggest problem with the responses to round two was that almost none of the participants filled out any of the "reason for response" portions of the questionnaires. In fact, only one participant did this at all, and then only for two questions. In round three the term "reason for response" was changed to "remarks" and the instructions for the third round stressed the need for remarks in the responses.

The logistics planner who responded to the AGE technician questionnaire instead of his own during round one did it again in round two. He was again contacted, re-sent the logistics planner questionnaire, and returned his responses. His responses to the AGE technician questionnaire were removed from the study.

Another participant had trouble with e-mail, so he was re-sent the questionnaire via FAX and returned his responses by FAX.

Round 3

Though not conducted, Round 3 would have repeated the Round 2 questionnaire but would have provided the justifications from Round 2 for consideration by all of the experts. The Round 3 questionnaire would also have requested critiques of the justifications of other experts.

Round 4

The Round 4 questionnaire would have repeated the questions from Round 3, and would have included the critiques from Round 3. Further discussion would only have been solicited if it appeared that additional rounds would have been required to achieve consensus.

IV. Results

The objectives of this chapter are to report the results of the Delphi study and to identify the problems encountered while performing the study. To do this the chapter will cover each of the Delphi rounds in order, from the preliminary round through the final round. Each rounds results will be reported, followed by the problems encountered during the round.

Preliminary Round

The preliminary round was conducted primarily to identify characteristics of Aerospace Ground Equipment (AGE) equipment for further study. The responses identified numerous characteristics for each piece of equipment included in the study. For each particular specialty (AGE technicians, load masters/boom operators, and logistics planners) each response was then developed into additional questions for following rounds. The additional questions developed will be reviewed in the following sub-sections based upon specific specialties.

In order to verify the participants' expertise, each participant was also asked in the preliminary round to assess their qualifications to judge transportability for each piece of AGE studied. With the exception of one participant, each indicated that they believed that they were in fact qualified to judge the transportability of the AGE in question. The one exception (a logistics planner) was removed from the study leaving only three participants.

At this point it would be beneficial to reiterate this study's definition of transportability which was included on all questionnaires which were sent to the participants. Transportability is the ability to quickly and efficiently prepare an item for transport, load the item on the transportation asset, remove the item from the transportation asset, and reconstitute the item for use.

All of the data from the study can be found in the appendices. Appendix A contains all of the data for AGE technician participants, including a question by question analysis of responses through each round of the study as well as an analysis of each participant's responses through each round. Appendix B contains the same data for load masters and boom operators, and Appendix C contains the data for logistics planners.

AGE Technicians

The questionnaire in the preliminary round for asked AGE technicians to identify how difficult each piece of equipment was to prepare for deployment. The scale was (1) extremely difficult, (2) moderately difficult, (3) routine, (4) moderately easy, and (5) extremely easy. The range of responses for the *dash 60* was from 2 to 3 with an average of 2.67. For the *dash 10* the range of responses was from 3 to 5, with an average of 4.33. For the *mule*, the range of responses was from 1 to 2, with an average of 1.67. For the *lite all* the responses were all 3.

Similarly, the preliminary round questionnaire asked for AGE technicians to identify how difficult each piece of equipment was to reconstitute after deployment using the same scale. For the *dash 60*, the responses ranged from 2 to 4, with an average of 3. The responses for the *dash 10* ranged from 3 to 5, with an average of 4.33. The mule's

responses ranged from 2 to 3, with an average of 2.33. The range of responses for the *lite all* was from 3 to 4, with an average of 3.33.

In the preliminary round, the AGE technician participants identified the following characteristics of the AM32A-60A (*dash 60*) which have an impact on its transportability: (1) ability of the *dash 60* to be forklifted, (2) the ability of the *dash 60* to be palletized, (3) the ability of the *dash 60* to be lifted by crane via sling points, (4) the high ground clearance, (5) the *dash 60's* large size, (6) the *dash 60's* large fuel capacity and two-tank fuel system, and (7) the disassembly requirements of the *dash 60.*

The AGE technicians identified the characteristics affecting the transportability of the AM32C-10 (*dash 10*) as: (1) the ability of the *dash 10* to be palletized, (2) the inability of the *dash 10* to be forklifted, (3) the ability of the *dash 10* to be lifted by crane via sling points, (4) the presence of hazardous materials in the *dash 10*, (5) the *dash 10's* size, (6) the single axle design of the *dash 10*, and (7) the disassembly requirements of the dash 10.

The AGE technicians also identified numerous characteristics of the TTU-228 (*mule*) which affect its transportability. The characteristics identified were: (1) the ability of the *mule* to be palletized, (2) the lack of ability to lift the *mule* with a forklift, (3) the large size of the *mule*, (4) the heavy weight of the *mule*, (5) the presence of hydraulic fluids in the *mule's* systems, and (6) the disassembly requirements for the mule.

The characteristics affecting transportability identified for the NF2-D (*lite all*) were: (1) the ability of the *lite all* to be palletized, (2) the ability of the *lite all* to be

forklifted, (3) the ground clearance of the *lite all*, and (4) the disassembly requirements for the *lite all.*

Load Masters and Boom Operators

The questionnaire in the preliminary round for asked load masters and boom operators to identify how difficult each piece of equipment was to incorporate into load plans. The scale was (1) extremely difficult, (2) moderately difficult, (3) routine, (4) moderately easy, and (5) extremely easy. The range of responses for the *dash 60* was from 3 to 5 with an average of 4.25. For the *dash 10* the range of responses was from 2 to 4, with an average of 3. For the *mule*, all of the responses were 3. For the *lite all* the range of responses was from 3 to 5, with an average of 4.5.

Similarly, the preliminary round questionnaire asked for load masters and boom operators to identify how difficult each piece of equipment was to load on an aircraft using the same scale. For the *dash 60*, the responses ranged from 3 to 5, with an average of 4. The responses for the *dash 10* ranged from 3 to 4, with an average of 3.25. The mule's responses were again all 3. The range of responses for the *lite all* was from 3 to 5, with an average of 4.5.

The characteristics of the *dash 60* identified were: (1) the overhang of a palletized *dash 60*, (2) the ability to roll-on/roll-off the *dash 60* from an aircraft, and (3) the high ground clearance of the *dash 60.*

The characteristics of the *dash 10* that affected transportability identified were: (1) the single axle design of the *dash 10*, (2) the *dash 10's* large size and heavy weight, and (3) the ability to roll-on/roll-off the *dash 10* from an aircraft.

For the *mule*, the characteristics identified were: (1) the *mule's* heavy weight, and (2) the ability to roll-on/roll-off the *mule* from an aircraft.

For the lite all, the characteristics that affected transportability were: (1) the *lite all's* light weight, (2) the ground clearance of the *lite all*, and (3) the ability to roll-on/roll-off the *lite all* from an aircraft.

Logistics Planners

The questionnaire in the preliminary round for asked logistics planners to identify how difficult each piece of equipment was to incorporate into load plans. The scale was (1) extremely difficult, (2) moderately difficult, (3) routine, (4) moderately easy, and (5) extremely easy. The range of responses for the *dash 60* was from 3 to 5 with an average of 4.25. For the *dash 10* the range of responses was from 2 to 4, with an average of 3. For the *mule*, all of the responses were 3. For the *lite all* the range of responses was from 3 to 5, with an average of 4.5.

Similarly, the preliminary round questionnaire asked for load masters and boom operators to identify how difficult each piece of equipment was to load on an aircraft using the same scale. For the *dash 60*, the responses ranged from 3 to 5, with an average of 4. The responses for the *dash 10* ranged from 3 to 4, with an average of 3.25. The mule's responses were again all 3. The range of responses for the *lite all* was from 3 to 5, with an average of 4.5.

For the *dash 60*, the only characteristic affecting transportability identified was its large fuel capacity. The *dash 10* also had only one characteristic affecting the transportability identified, the lack of an internal combustion engine.

The characteristics of the *mule* which impacted its transportability were: (1) its large size, and (2) its hydraulic system and fluids.

The characteristics of the lite all which impacted its transportability that were identified by the participants were: (1) the simple internal combustion engine type, (2) the small fuel tank, and (3) the requirement to stow the large external flood lights.

Cargo Limitations of Air Force Aircraft

Each participant in the load master/boom operator group and the logistics planner group was asked, "In your experience, when an aircraft is considered 'fully loaded' with cargo, what percentage of the time has the aircraft been limited by: (a) aircraft floor/pallet space, (b) aircraft volume (cube), and (c) aircraft maximum weight." Surprisingly, the results varied widely, both within each of the two groups and between the two groups.

The responses from the load masters/boom operators indicate that an aircraft is limited by its floor/pallet space 45-98 percent of the time; it is limited by volume 5-45 percent of the time; and is limited by weight 2-45 percent of the time. The responses from logistics planners indicate that an aircraft is limited by its floor/pallet space 10-25 percent of the time; by its volume 5-30 percent of the time; and by weight 60-70 percent of the time. This question was not intended to be part of the main Delphi study, but simply a one time question to gather data. The preliminary round responses, however, were so varied that it was decided to give feedback to the participants about the preliminary round responses and repeat the question during round 1.

Round One

The first round of the study was conducted as the formal beginning of the Delphi process and included all of scaled questions from the preliminary round along with the questions developed from the preliminary round responses about the transportability characteristics of AGE. Questions for which a consensus was reached were removed from the round two questionnaires.

AGE Technicians

For the questions that were previously asked in the preliminary round the first round results were mixed because the range of responses for most of the questions did not narrow, and in fact some of the response ranges widened. The range of responses for the question, "How difficult is the *mule* to prepare for deployment?" increased from 1-2 in the preliminary round to 1-3 in the first round. Also, the range of responses to the question, "How difficult is the *lite all* to reconstitute (prepare for use) after deployment?" increased from 3-3 to 3-4.

One of the questions did show a convergence on toward an answer. The range of responses for the question, "How difficult is the *dash 60* to reconstitute (prepare for use) after deployment?" decreased from 2-4 in the preliminary round to 3-4 in the first round. All of the remaining questions yielded an unchanged response range.

For many of the questions added after the preliminary round the participants achieved an immediate consensus. For the question, "What effect does the *dash 60's* ability to be forklifted have on the *dash 60's* transportability?" the respondents agreed that it **significantly improved** the transportability of the *dash 60.* For the question,

"What effect does the *dash 60's* size have on the *dash 60's* transportability?" the participants agreed that it has **no effect** on the transportability of the *dash 60.* For the question, "What effect does the amount of disassembly [required to deploy] (or lack thereof) have on the *dash 60's* transportability?" the participants agreed that it has **no effect** on the transportability of the *dash 60.*

For the question, "What effect does the *dash 10's* lack of ability to be forklifted have on the *dash 10's* transportability?" the respondents agreed that it **moderately degrades** the transportability of the *dash 10.* For the question, "How much disassembly is required to prepare the *dash 10* for transport?" the respondents agreed that **no disassembly** was required. For the question, "What effect does the *dash 10's* amount of disassembly [required to deploy] (or lack thereof) have on the *dash 10's* transportability?" the respondents agreed that it had **no effect**.

For the question, "What effect does the *mule's* size have on the *mule's* transportability" the participants agreed that it **moderately degraded** its transportability. For the question, "What effect does the mule's weight have on the mule's transportability?" the respondents agreed that it **moderately degraded** the *mule's* transportability. For the question, "What effect does the *mule's* hydraulic fluids have on the mule's transportability?" the respondents agreed that it **moderately degraded** the *mule's* transportability. For the question, "What effect does the *mule's* amount of disassembly [required to deploy] (or lack thereof) have on the *mule's* transportability?" the participants agreed that it had **no effect**.

The participants only reached consensus on one question regarding the *lite all*. For the question, "What effect does the *lite all's* large size have on the *lite alls* transportability?" the respondents agreed that it had **no effect**.

Load Masters and Boom Operators

For the questions that were previously asked in the preliminary round the first round results were good in that the range of responses for one question narrowed, and some responses indicated consensus. The range of responses for the question, "How difficult is the *dash 10* to incorporate into load plans?" narrowed from 2-4 to 2-3. The respondents reached consensus on the questions, "How difficult is the *mule* to incorporate into load plans?" and, "How difficult is the *mule* to load on an aircraft?" For both of these questions the consensus was that the tasks were **routine**.

The participants also achieved consensus on one question added after the preliminary round. For the question, "What effect does the *lite all's* weight have on the *lite all's* transportability?" the respondents agreed that it had **no effect** on the transportability.

Logistics Planners

For the questions that were previously asked in the preliminary round the first round results were mixed because the range of responses actually diverged for three questions. The range of responses for the question, "How difficult is the *dash 60* to incorporate into load plans?" increased from 3-4 in the preliminary round to 3-5 in the first round. The range of responses to the question, "How difficult is the *dash 10* to

prepare for transportation?" increased from 4-5 to 3-5. Also, the range of responses to the question, "How difficult is the *mule* to incorporate into load plans?" increased from 3-4 in the preliminary round to 3-5 in the first round.

Consensus was reached on three questions originally asked in the preliminary round. For the question, "How difficult is the *dash 60* to prepare for transportation?" the respondents agreed that it was **routine**. For the question, "How difficult is the *mule* to prepare for transportation?" the participants agreed that it was **moderately difficult**. For the question, "How difficult is the *lite all* to prepare for transportation?" the respondents agreed that it was **routine**.

Limitations of Air Force Cargo Aircraft

Once again each participant in the load master/boom operator group and the logistics planner group was asked, "In your experience, when an aircraft is considered 'fully loaded' with cargo, what percentage of the time has the aircraft been limited by: (a) aircraft floor/pallet space, (b) aircraft volume (cube), and (c) aircraft maximum weight." In the first round, the responses from the load masters/boom operators indicate that an aircraft is limited by its floor/pallet space 75-98 percent of the time (vs. 45-98 in the preliminary round); it is limited by volume 0-5 percent of the time (vs. 5-45 in the preliminary round); and is limited by weight 2-20 percent of the time (vs. 2-45 in the preliminary round). The responses from logistics planners indicate that an aircraft is limited by its floor/pallet space 20-75 percent of the time (vs. 10-25 in the preliminary round); by its volume 10-20 percent of the time (vs. 5-30 in the preliminary round); and by weight 15-70 percent of the time (vs. 60-70 in the preliminary round). As can be seen,

the ranges of responses were narrowed considerably load master/boom operator group, but widened considerably for the logistics planner group. Note that feedback from the was only provided to participants from preliminary round responses within their group, i.e. the logistics planners received only information about the responses of all of the participating logistics planners, and load masters/boom operators only received information about the responses of all of the participating load masters and boom operators.

Round Two

Round two was conducted in the same manner as round one. Questions for which a consensus was reached were removed from the round three questionnaires.

AGE Technicians

The results from the second round were very favorable, because consensus was achieved on several questions. In addition there were no questions which had the range of responses increase. For the question, "How much disassembly is required to prepare the *mule* for transport?" the range of responses decreased from 2-4 in round one to 3-4 in round two. For the question, "What effect does the *dash 60's* ability to be palletized have on the *dash 60's* transportability?" the range shifted from 4-5 in round one to 3-4 in round two.

Consensus was reached on the following questions about the *dash 60*. For the question, "How difficult is the *dash 60* to reconstitute (prepare for use) after deployment?" the consensus was that it was **routine**. For the question, "What effect does

the *dash 60's* lack of sling points have on the *dash 60's* transportability?" the consensus was that it had **no effect**. For the question, "What effect does the *dash 60's* fuel system have on the *dash 60's* transportability?" the participants agreed that it had **no effect.**

Consensus was also reached on the following questions about the *dash 10.* For the question, "What effect does the *dash 10's* ability to be palletized have on the *dash 10's* transportability?" the consensus was that it had **no effect**. For the question, "What effect do the *dash 10's* sling points have on the *dash 10's* transportability?" the consensus was that there was **no effect**. For the question, "What effect do the *dash 10's* hazardous materials have on the *dash 10's* transportability?" the consensus was that there was **no effect**. For the question, "What effect does the *dash 10's* size have on the *dash 10's* transportability?" the consensus was again **no effect.**

Consensus was reached on one question for the *mule*. "What effect does the *mule's* ability to be palletized have on the *mule's* transportability?" resulted in a consensus that it had **no effect.**

Consensus was also reached on the following questions about the *lite all*. For the question, "How difficult is the *lite all* to prepare for deployment?" the experts decided that it was **routine**. For the question, "How difficult is the *lite all* to reconstitute (prepare for use) after deployment?" the consensus was that it was **routine**. For the question, "What effect does the *lite all's* ability to be palletized have on the *lite all's* transportability?" the participants agreed that it had **no effect**. For the question, "What effect does the *lite all's* ability to be forklifted have on the *lite all's* transportability?" the consensus was that it **moderately improved** the transportability.

Load Masters and Boom Operators

The results for the load masters and boom operators for round two were also favorable since consensus was reached on a number of questions, and convergence was evident on two others. Divergence was also evident on one question. For the question, "What effect does the *dash 60's* rolling stock characteristic (roll-on/roll-off) have on the *dash 60's* transportability?" the range decreased from 3-5 in round one to 3-4 in round two. For the question, "What effect does the *dash 60's* ground clearance have on the *dash 60's* transportability?" the range decreased from 3-5 in round one to 3-4 in round two. The question, "How difficult is the dash 10 to incorporate into load plans?" resulted in an increase in range from 2-3 in round one to 2-4 in round two. This returned the range to what it was in the preliminary round.

Consensus was achieved on the following questions. For the question, "What effect does the *dash 10's* single axle design have on the *dash 10's* transportability?" the consensus was that it had **no effect**. For the question, "What effect does the *dash 10's* size and weight have on the *dash 10's* transportability?" the participants agreed that they had **no effect**. For the question, "What effect does the *dash 10's* rolling stock characteristic (roll-on/roll-off) have on the *dash 10's* transportability?" the consensus was that it had **no effect**. For the question, "How difficult is the *mule* to incorporate into load plans?" the respondents agreed that it is **routine**. For the question, "How difficult is the *mule* to load on an aircraft?" the consensus was that it is **routine**. For the question, "How difficult is the *lite all* to incorporate into load plans?" the participants agreed that it is **extremely easy**.

Logistics Planners

The logistics planner group results for round two were poor in that consensus was only reached on one question, and convergence was only apparent on one other question while divergence was evident on four questions. For the question "How difficult is the *mule* to incorporate into load plans?" all participants agreed that it was **routine**. Convergence was evident in the responses to the question "What effect does the *dash 10's* lack of an internal engine have on the *dash 10's* transportability?" where the range decreased from 3-5 in round one to 4-5 in round two.

On the other hand four questions showed divergence. For the question, "How difficult is the *dash 60* to martial between holding points?" the range increased from 3-4 in round one to 2-4 in round two. For the question, "How difficult is the *dash 10* to martial between cargo holding points?" the range increased from 3-4 in round one to 2-4 in round two. For the question, "How difficult is the *mule* to martial between cargo holding points?" the range increased from 3-4 in round one to 2-5 in round two. For the question, "What effect does the *lite all's* simple internal combustion engine have on the light all's transportability?" the range increased from 3-4 in round one to 2-4 in round two.

Consensus was reached on the following question, "How difficult is the *mule* to incorporate into load plans?" The consensus was that it was **routine**.

Rounds Three and Four

The study was terminated for lack of time before the responses to round three were received. The problems with the preliminary round and rounds one and two caused

delays that forced the study's termination. The impact of not accomplishing these rounds are that consensus was not reached on all questions, though some questions showed no signs of approaching a consensus anyway. Since the round two responses generally lacked justifications of participant responses, feedback to the participants to generate further movement toward consensus was not available. Therefore round three would likely not have yielded vastly different results from the rounds already accomplished. Unless the round three responses would have resulted in significantly more remarks than the round two questionnaires did, it is unlikely that round four would have yielded much better results either.

Final Results

The final results of the study are included in the following tables. Table 4 summarizes the results for each question on the AGE technician questionnaires. Table 5 is the summary of results for each question on the load master/boom operator questionnaires, and table 6 is the summary of results for each question on the logistics planner questionnaires.

Table 4. Summary of Results, AGE Technicians

Question	Range	Mean
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to prepare for deployment?	2 - 3	2.67
1.b How difficult is the "dash 60" to reconstitute (prepare for use) after deployment?	2 - 4	3.00
1.c What effect does the "dash 60's" ability to be forklifted have on the "dash 60's" transportability?	5 - 5	5.00
1.d What effect does the "dash 60's" ability to be palletized have on the "dash 60's" transportability?	3 - 4	3.50
1.e What effect does the "dash 60's" lack of sling points have on the "dash 60's" transportability?	3 - 3	3.00

1.f	What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?	3 - 4	3.33
1.g	What effect does the "dash 60's" size have on the "dash 60's" transportability?	3 - 3	3.00
1.h	What effect does the "dash 60's" fuel system have on the "dash 60's" transportability?	3 - 3	3.00
1.i	How much disassembly is required to prepare the "dash 60" for transport?	3 - 4	3.67
1.j	What effect does the "dash 60's" amount of disassembly (or lack thereof) have on the "dash 60's" transportability?	3 - 3	3.00
2.a	How difficult is the AM32C-10 air conditioner ("dash 10") to prepare for deployment?	3 - 5	4.00
2.b	How difficult is the "dash 10" to reconstitute (prepare for use) after deployment?	3 - 5	3.67
2.c	What effect does the "dash 10's" ability to be palletized have on the "dash 10's" transportability?	3 - 3	3.00
2.d	What effect does the "dash 10's" lack of ability to be forklifted have on the "dash 10's" transportability?	2 - 2	2.00
2.e	What effect does the "dash 10's" sling points have on the "dash 10's" transportability?	3 - 3	3.00
2.f	What effect do the "dash 10's" hazardous materials have on the "dash 10's" transportability?	3 - 3	3.00
2.g	What effect does the "dash 10's" size have on the "dash 10's" transportability?	3 - 3	3.00
2.h	What effect does the "dash 10's" single-axle design have on the "dash 10's" transportability?	2 - 3	2.50
2.i	How much disassembly is required to prepare the "dash 10" for transport?	5 - 5	5.00
2.j	What effect does the "dash 10's" amount of disassembly (or lack thereof) have on the "dash 10's" transportability?	3 - 3	3.00
3.a	How difficult is the TTU-228 hydraulic test stand ("mule") to prepare for deployment?	1 - 3	1.67
3.b	How difficult is the "mule" to reconstitute (prepare for use) after deployment?	2 - 3	2.67
3.c	What effect does the "mule's" ability to be palletized have on the "mule's" transportability?	3 - 3	3.00
3.d	What effect does the "mule's" lack of ability to be forklifted have on the "mule's" transportability?	1 - 2	1.50
3.e	What effect does the "mule's" size have on the "mule's" transportability?	2 - 2	2.00
3.f	What effect do the "mule's" hydraulic fluids have on the "mule's" transportability?	2 - 2	2.00

3.g	What effect does the "mule's" weight have on the "mule's" transportability?	2 - 2	2.00
3.h	How much disassembly is required to prepare the "mule" for transport?	3 - 4	3.33
3.i	What effect does the "mule's" amount of disassembly (or lack thereof) have on the "mule's" transportability?	3 - 3	3.00
4.a	How difficult is the NF2-D external lighting cart ("light all") to prepare for deployment?	3 - 3	3.00
4.b	How difficult is the NF2-D ("light all") to reconstitute (prepare for use) after deployment?	3 - 3	3.00
4.c	What effect does the "light all's" ability to be palletized have on the "light all's" transportability?	3 - 3	3.00
4.d	What effect does the "light all's" ability to be forklifted have on the "light all's" transportability?	4 - 4	4.00
4.e	What effect does the "light all's" ground clearance have on the "light all's" transportability?	3 - 4	3.33
4.f	What effect does the "light all's" large size have on the "light all's" transportability?	3 - 3	3.00
4.g	How much disassembly is required to prepare the "light all" for transport?	3 - 4	3.33
4.h	What effect does the "light all's" amount of disassembly (or lack thereof) have on the "light all's" transportability?	3 - 4	3.50

Table 5. Summary of Results, Load Masters/Boom Operators

Question	Range	Mean
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?	3 - 5	4
1.b How difficult is the "dash 60" to load on an aircraft?	3 - 5	4
1.c What effect does the "dash 60" pallet overhang have on the "dash 60's" transportability?	2 - 3	2.5
1.d What effect does the "dash 60s" rolling stock characteristics (roll-on/roll-off) have on the "dash 60's" transportability?	3 - 4	3.5
1.e What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?	3 - 4	3.5
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?	2 - 4	3
2.b How difficult is the "dash 10" to load on an aircraft?	3 - 4	3.25
2.c What effect does the "dash 10's" single axle design have on the "dash 10's" transportability?	3 - 3	3
2.d What effect does the "dash 10's" size and weight have on the "dash 10's" transportability?	3 - 3	3
2.e What effect does the "dash 10s" rolling stock characteristics (roll-on/roll-off) have on the "dash 10's" transportability?	3 - 3	3
3.a How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?	3 - 3	3
3.b How difficult is the "mule" to load on an aircraft?	3 - 3	3
3.c What effect does the "mule's" weight have on the "mule's" transportability?	3 - 3	3
3.d What effect does the "mule's" rolling stock characteristics (roll-on/roll-off) have on the "mule's" transportability?	3 - 4	3.75
4.a How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?	5 - 5	5
4.b How difficult is the "light all" to load on an aircraft?	3 - 5	4.25
4.c What effect does the "light all's" weight have on the "light all's" transportability?	3 - 3	3
4.d What effect does the "light all's" ground clearance have on the "light all's" transportability?	3 - 4	3.25
4.e What effect does the "light all's" rolling stock characteristics (roll-on/roll-off) have on the "light all's" transportability?	3 - 4	3.5

Table 6. Summary of Results, Logistics Planners

Question	Range	Mean
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?	3 - 5	3.67
1.b How difficult is the "dash 60" to martial between cargo holding points?	2 - 4	3.00
1.c How difficult is the "dash 60" to prepare for transportation?	3 - 3	3.00
1.d What effect does the "dash 60's" fuel system (its large fuel capacity) have on the "dash 60's" transportability?	2 - 3	2.67
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?	3 - 5	3.67
2.b How difficult is the "dash 10" to martial between cargo holding points?	2 - 4	3.00
2.c How difficult is the "dash 10" to prepare for transportation?	3 - 5	4.00
2.d What effect does the "dash 10's" lack of an internal engine have on the "dash 10's" transportability?	4 - 5	4.67
3.a How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?	3 - 3	3.00
3.b How difficult is the "mule" to martial between cargo holding points?	2 - 5	3.33
3.c How difficult is the "mule" to prepare for transportation?	2 - 2	2.00
3.d What effect does the "mule's" large size have on the "mule's" transportability?	2 - 3	2.67
3.e What effect does the "mule's" hydraulic system have on the "mule's" transportability?	2 - 3	2.67
4.a How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?	3 - 5	3.67
4.b How difficult is the "light all" to martial between cargo holding points?	3 - 5	3.67
4.c How difficult is the NF2-D ("light all") to prepare for transportation?	3 - 3	3.00
4.d What effect does the "light all's" simple internal combustion engine have on the "light all's" transportability?	2 - 4	3.00
4.e What effect does the "light all's" small fuel tank have on the "light all's" transportability?	3 - 4	3.33
4.f What effect do the "light all's" large flood lights have on the "light all's" transportability?	2 - 3	2.67

V. Conclusions

This chapter presents the conclusions drawn from the study and provides suggestions for future research. The conclusions drawn include the apparent positive and negative characteristics of the Air Force's current Aerospace Ground Equipment (AGE) inventory according to the opinions of experts in the field. In addition, this chapter includes a brief discussion about the implications of the neutral attitudes of the experts studied, as well as a discussion of the appropriateness of the study's methodology.

Again, the definition of transportability used in this study is the ability to quickly and efficiently prepare an item for transport, load the item on the transportation asset, remove the item from the transportation asset, and reconstitute the item for use. These four aspects can be divided into two areas, loading and unloading, and preparing for and reconstituting after shipment. The following discussion of the positive and negative transportability characteristics will include these two areas, where the inputs of the load masters/boom operators and the logistics planners will be assumed to involve the loading/unloading area and the inputs of the AGE technicians will be interpreted to involve the preparation/reconstitution area. Table 7 summarizes the characteristics of AGE and their effects on transportability.

Positive Transportability Characteristics of AGE

The characteristics identified by the experts in this study that most positively impact AGE transportability include the ability to be forklifted, the ability to be rolled-on and off the aircraft, a high ground clearance, and a small fuel tank. The AGE technicians

agreed that being able to forklift the *dash 60* **significantly improved** its transportability, and moderately improved the transportability of the *lite all*, while not being able to forklift the *dash 10* **moderately degraded** its transportability. The inability of the mule to be forklifted also clearly reduced its transportability.

The ability to roll equipment on and off of an aircraft was determined to improve its transportability according to load masters and boom operators, though not as dramatically. Expert opinions on roll-on/roll-off capability ranged from no effect to moderately improved transportability for the *dash 60*, *mule*, and *lite all*. For the *dash 10* the experts agreed that roll-on/roll-off capability had no effect on its transportability, possibly due to its single axle design which would make it more difficult to roll-on/roll-off without a large amount of manpower or external drive source (prime mover or winch).

Ground clearance seemed to be considered another plus by load masters and boom operators, expert opinions ranging from no effect to moderately improved transportability for the dash 60 and lite all due to high ground clearance. Clearly ground clearance is an important factor in rolling equipment on and off of aircraft with loading ramps (like the C-5, C-17, and C-141), but perhaps the lack of dramatic opinions reflect the fact that the ground clearance of the current AGE fleet is more than adequate.

Negative Transportability Characteristics of AGE

Factors that were viewed by the participants as negative transportability characteristics included large size (but only for the *mule*), the presence of hydraulic fluids, the single axle design of the *dash 10*, large fuel capacities, and pallet overhang.

Large size tended to be a negative factor for transportability, the *mule* was considered to be large enough and heavy enough to degrade transportability. AGE technicians agreed that the large size and heavy weight of the *mule* moderately degraded its transportability, while stating that the size and weight of the *dash 60*, *dash 10*, and *lite all* all had no effect on their transportability. Load masters and boom operators, however, were of the opinion that size had no impact on the transportability of the *mule*.

AGE technicians agreed that the presence of hydraulic fluid moderately degraded the transportability of the *mule*, but the importance of this consensus is limited by the fact that it is unlikely that any future hydraulic test stand will be able to be designed not to have some quantity of hydraulic fluid present.

AGE technicians seemed to think that the single axle design moderately reduced the transportability of the *dash 10*. Opinions ranged from moderate degradation of the *dash 10's* transportability to no effect. Load masters and boom operators achieved a consensus that it had no effect.

Large fuel capacity was considered by some logistics planners to reduce the transportability of the *dash 60*, while the small capacity of the *lite all* was seen to enhance its transportability. The opinions of the logistics planners ranged from moderate degradation to no effect on transportability for the *dash 60* due to its large fuel tanks, and from no effect to moderate improvement of the transportability for *lite all* due to its small fuel capacity. Any way to reduce fuel requirements (and therefore on-board capacity) would therefore provide some improvement in transportability.

Load masters and boom operators did not achieve a consensus about the impact of pallet overhang on the dash 60. Opinions ranged from no effect on transportability to moderate degradation of transportability due to pallet overhang.

Neutral Characteristics of AGE

Issues that experts agreed did not alter the transportability of AGE included palletization, sling points/crane lifting, and disassembly.

AGE technicians agreed that the ability to palletize AGE for deployment did not in fact enhance its transportability with the possible exception of the *dash 60* where one of the participants thought that it moderately improved the *dash 60's* transportability. AGE technicians achieved consensus regarding the ability of the dash 60 and dash 10 to be lifted by crane via sling points. All of the AGE technicians agreed that the lack of sling points on the dash 60 had no effect on the dash 60's transportability, and that the presence of sling points on the dash 10 also had no effect on the dash 10's transportability.

AGE technicians also agreed that the amount of disassembly required to prepare AGE equipment for transportation had no effect on its transportability, except for the *lite all* where opinions ranged from no effect on transportability to moderate improvement of transportability.

Table 7. Characteristic Effects

Impact	Area Impacted: Loading/Unloading	Area Impacted: Preparation/Reconstitution
Positive	- Roll-on/Roll-Off ability - High Ground Clearance	- Forkliftabilty
Neutral		- Palletization - Crane Liftability/Sling Points - Disassembly Requirements
Negative	- Large Fuel Capacity - Pallet Overhang	- Large Size - Heavy Weight - Hydraulic Fluids - Single Axle Design

Research Questions Answered

The answers to the first two research questions posed in chapter 1 ("What transportability problems exist in the Air Force's currently fielded power AGE designs?" and "What improvements can be incorporated into the MASS program to improve the transportability of the MASS equipment?") naturally follow from the above discussion. The currently fielded powered AGE systems suffer from designs that require large fuel capacity, hydraulic fluids, and are to large to fit into a single pallet position (pallet overhang). Other problems include heavy weight, and one piece suffers from problems caused by a single axle design. Improvements that could be incorporated into the MASS program include the reduction of fuel requirements in power plants, the minimization of hydraulic fluid capacity requirements, avoidance of single axle designs, and to the largest extent possible the reduction in size and weight emphasizing the elimination of pallet overhang.

The answer to the third research question posed in chapter 1 ("What is the limiting factor in deployment of Air Force units, the weight of equipment, the volume of the

equipment, or the amount of floor space of the cargo bay used?") is floor space/pallet positions seems to be the limiting factor. This was clearly evident from the load master and boom operator responses (75-98 percent of the time floor space/pallet positions was the limiting factor), but was less clear in the logistics planner responses which were more evenly split between floor space/pallet position and aircraft maximum weight limitations.

Unexpected Results

It appears from the results of this study that the experts do not have strong opinions about the transportability characteristics of the Air Force's current AGE. This might reflect either an attitude of apathy towards improving the transportability of AGE, a general lack of ideas for improving the transportability of AGE, or possibly a problem with the methodology of the study. The issue of apathy will be addressed first. From the cooperation received from the participants while conducting the study there is no reason to think that they are apathetic about the transportability issues. It was not unusual to send out the ten questionnaires in the morning and get back three of them the same day. By the second day there would usually be seven or eight questionnaires returned. This indicates that the participants were more than willing to try to participate and achieve the goals of the study.

The appropriateness of the methodology is another possible cause of the problems with the study results. As could be seen by the lack of justifications of responses in round two of the study, it did appear that the participants were getting a little tired of answering the same questions over and over. Perhaps the forming of focus groups would have yielded satisfactory results. One drawback to this type of methodology would have

been a significant impact on the units involved in the study as people were removed from their normal jobs to attend the sessions. It is less likely that the participating bases would have agreed to participate if the impact of the study on their operations would have been significant. Another drawback of the focus group methodology would have been the interpersonal issues involved in group dynamics, the very reason that the Delphi method was developed in the first place.

It seems that the most likely reason for the disappointing results of this study is the fact that the experts in the field don't really have any dramatic and new ideas for improving the transportability of the current AGE. Maybe the AGE we currently have is as transportable as AGE can reasonably be (according to my definition of transportability anyway). This does not mean that the greater issue of deployability or the size of the mobility footprint are any less important. New AGE systems like the those being developed in the MASS program could still reduce the footprint of combat units by reducing the amount of AGE that needed to be moved. This new support equipment, however, should be designed with transportability in mind.

Suggestions for Further Research

Further research to build upon the lessons learned in this study could be accomplished with a similar Delphi method, or with focus groups or structured interviews. Larger groups may have yielded more ideas and more transportability characteristics of AGE in the preliminary round. Other suggestions for these studies would be to include transportation personnel and exclude logistics planners since the logistics planners seemed to be the ones that had to find other experts the most often.

Another area that might lead to some transportability improvements might be the actual field study to determine how long it takes to prepare AGE for shipment, to move it to and between the marshaling points, to load it on aircraft, to remove it from aircraft, and to reconstitute it after shipment. This type of study might lead to insight into how to improve the transportability of current and future AGE systems.

Concluding Thoughts

In the end, this study only attacked one small issue of the larger issue of mobility. The fact that experts seem to feel that the transportability characteristics of the Air Force's current powered AGE are overall acceptable does not necessarily mean that the same AGE has no impact on mobility. The amount of AGE to be moved and the amount of people and equipment required to support that AGE can be staggering. Any reduction in the amount of AGE required could decrease the mobility footprint of Air Force units, and significantly improve the mobility posture of Air Force.

Appendix A. Data Analysis: AGE Technician Questionnaires

Analysis by Question, AGE Technicians

Question	Cannon	Moody	Pope	Range	Mean
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to prepare for deployemnnt?					
Round 0	3	2	3	2 - 3	2.67
Round 1	3	2	3	2 - 3	2.67
Round 2	3	2	3	2 - 3	2.67
1.b How difficult is the "dash 60" to reconstitute (prepare for use) after deployment?					
Round 0	4	2	3	2 - 4	3.00
Round 1	4	3	3	3 - 4	3.33
Round 2	3	3	3	3 - 3	3.00
1.c What effect does the "dash 60's" ability to be forklifted have on the "dash 60's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	5	-	5	5 - 5	5.00
Round 2	-	-	-	0 - 0	0.00
1.d What effect does the "dash 60's" ability to be palletized have on the "dash 60's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	-	5	4 - 5	4.50
Round 2	4	-	3	3 - 4	3.50
1.e What effect does the "dash 60's" lack of sling points have on the "dash 60's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	2	-	3	2 - 3	2.50
Round 2	3	-	3	3 - 3	3.00
1.f What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	4	3	3 - 4	3.67
Round 2	3	4	3	3 - 4	3.33
1.g What effect does the "dash 60's" size have on the "dash 60's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	-	3	3 - 3	3.00
Round 2	-	-	-	0 - 0	0.00
1.h What effect does the "dash 60's" fuel system have on the "dash 60's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	4	3	3 - 4	3.33
Round 2	3	3	3	3 - 3	3.00
Round 3	0	0	0	0 - 0	0.00
1.i How much disassembly is required to prepare the "dash 60" for transport?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	3	4	3 - 4	3.67
Round 2	4	3	4	3 - 4	3.67

1.j What effect does the "dash 60's" amount of disassembly (or lack thereof) have on the "dash 60's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	3	3	3 - 3	3.00
Round 2	-	-	-	0 - 0	0.00
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to prepare for deployment?					
Round 0	5	3	5	3 - 5	4.33
Round 1	5	3	3	3 - 5	3.67
Round 2	5	3	4	3 - 5	4.00
2.b How difficult is the "dash 10" to reconstitute (prepare for use) after deployment?					
Round 0	5	3	5	3 - 5	4.33
Round 1	5	4	3	3 - 5	4.00
Round 2	5	3	3	3 - 5	3.67
2.c What effect does the "dash 10's" ability to be palletized have on the "dash 10's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	-	3	3 - 4	3.50
Round 2	3	-	3	3 - 3	3.00
2.d What effect does the "dash 10's" lack of ability to be forklifted have on the "dash 10's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	2	-	2	2 - 2	2.00
Round 2	-	-	-	0 - 0	0.00
Round 3	0	0	0	0 - 0	0.00
2.e What effect does the "dash 10's" sling points have on the "dash 10's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	-	3	3 - 4	3.50
Round 2	3	-	3	3 - 3	3.00
2.f What effect do the "dash 10's" hazardous materials have on the "dash 10's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	5	-	3	3 - 5	4.00
Round 2	3	3	3	3 - 3	3.00
2.g What effect does the "dash 10's" size have on the "dash 10's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	5	-	3	3 - 5	4.00
Round 2	3	-	3	3 - 3	3.00
2.h What effect does the "dash 10's" single-axle design have on the "dash 10's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	-	2	2 - 3	2.50
Round 2	2	-	3	2 - 3	2.50
2.i How much disassembly is required to prepare the "dash 10" for transport?					
Round 0	-	-	-	0 - 0	0.00
Round 1	5	5	5	5 - 5	5.00
Round 2	-	-	-	0 - 0	0.00

2.j What effect does the "dash 10's" amount of disassembly (or lack thereof) have on the "dash 10's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	3	3	3 - 3	3.00
Round 2	-	-	-	0 - 0	0.00
3.a How difficult is the TTU-228 hydraulic test stand ("mule") to prepare for deployment?					
Round 0	2	1	2	1 - 2	1.67
Round 1	1	1	3	1 - 3	1.67
Round 2	1	1	3	1 - 3	1.67
3.b How difficult is the "mule" to reconstitute (prepare for use) after deployment?					
Round 0	3	2	2	2 - 3	2.33
Round 1	2	2	3	2 - 3	2.33
Round 2	2	3	3	2 - 3	2.67
3.c What effect does the "mule's" ability to be palletized have on the "mule's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	1	-	3	1 - 3	2.00
Round 2	3	-	3	3 - 3	3.00
3.d What effect does the "mule's" lack of ability to be forklifted have on the "mule's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	1	-	2	1 - 2	1.50
Round 2	1	-	2	1 - 2	1.50
3.e What effect does the "mule's" size have on the "mule's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	2	-	2	2 - 2	2.00
Round 2	-	-	-	0 - 0	0.00
3.f What effect do the "mule's" hydraulic fluids have on the "mule's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	2	2	2	2 - 2	2.00
Round 2	-	-	-	0 - 0	0.00
3.g What effect does the "mule's" weight have on the "mule's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	2	-	2	2 - 2	2.00
Round 2	-	-	-	0 - 0	0.00
3.h How much disassembly is required to prepare the "mule" for transport?					
Round 0	-	-	-	0 - 0	0.00
Round 1	2	3	4	2 - 4	3.00
Round 2	3	3	4	3 - 4	3.33
3.i What effect does the "mule's" amount of disassembly (or lack thereof) have on the "mule's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	3	3	3 - 3	3.00
Round 2	-	-	-	0 - 0	0.00

4.a How difficult is the NF2-D external lighting cart ("light all") to prepare for deployment?					
Round 0	3	3	3	3 - 3	3.00
Round 1	4	3	3	3 - 4	3.33
Round 2	3	3	3	3 - 3	3.00
4.b How difficult is the NF2-D ("light all") to reconstitute (prepare for use) after deployment?					
Round 0	3	3	4	3 - 4	3.33
Round 1	4	3	3	3 - 4	3.33
Round 2	3	3	3	3 - 3	3.00
4.c What effect does the "light all's" ability to be palletized have on the "light all's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	-	3	3 - 4	3.50
Round 2	3	-	3	3 - 3	3.00
4.d What effect does the "light all's" ability to be forklifted have on the "light all's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	-	5	4 - 5	4.50
Round 2	4	-	4	4 - 4	4.00
4.e What effect does the "light all's" ground clearance have on the "light all's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	4	3	3 - 4	3.33
Round 2	3	4	3	3 - 4	3.33
4.f What effect does the "light all's" large size have on the "light all's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	-	3	3 - 3	3.00
Round 2	-	-	-	0 - 0	0.00
4.g How much disassembly is required to prepare the "light all" for transport?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	3	4	3 - 4	3.67
Round 2	4	3	3	3 - 4	3.33
4.h What effect does the "light all's" amount of disassembly (or lack thereof) have on the "light all's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	4	3	3 - 4	3.67
Round 2	4	-	3	3 - 4	3.50

Where consensus was reached the results are boxed.

Analysis by Participant, Cannon AGE Technician

Question		Round 0	Range	Round 1	Range	Round 2	Range
1.a	How difficult is the AM32A-60A turbine powered generator ("dash 60") to prepare for deployment?	3	2 - 3	3	2 - 3	3	2 - 3
1.b	How difficult is the "dash 60" to reconstitute (prepare for use) after deployment?	4	2 - 4	4	3 - 4	3	3 - 3
1.c	What effect does the "dash 60's" ability to be forklifted have on the "dash 60's" transportability?	-	0 - 0	5	5 - 5	-	0 - 0
1.d	What effect does the "dash 60's" ability to be palletized have on the "dash 60's" transportability?	-	0 - 0	4	4 - 5	4	3 - 4
1.e	What effect does the "dash 60's" lack of sling points have on the "dash 60's" transportability?	-	0 - 0	2	2 - 3	3	3 - 3
1.f	What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?	-	0 - 0	4	3 - 4	3	3 - 4
1.g	What effect does the "dash 60's" size have on the "dash 60's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0
1.h	What effect does the "dash 60's" fuel system have on the "dash 60's" transportability?	-	0 - 0	3	3 - 4	3	3 - 3
1.i	How much disassembly is required to prepare the "dash 60" for transport?	-	0 - 0	4	3 - 4	4	3 - 4
1.j	What effect does the "dash 60's" amount of disassembly (or lack thereof) have on the "dash 60's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0
2.a	How difficult is the AM32C-10 air conditioner ("dash 10") to prepare for deployment?	5	3 - 5	5	3 - 5	5	3 - 5
2.b	How difficult is the "dash 10" to reconstitute (prepare for use) after deployment?	5	3 - 5	5	3 - 5	5	3 - 5
2.c	What effect does the "dash 10's" ability to be palletized have on the "dash 10's" transportability?	-	0 - 0	4	3 - 4	3	3 - 3
2.d	What effect does the "dash 10's" lack of ability to be forklifted have on the "dash 10's" transportability?	-	0 - 0	2	2 - 2	-	0 - 0
2.e	What effect does the "dash 10's" sling points have on the "dash 10's" transportability?	-	0 - 0	4	3 - 4	3	3 - 3
2.f	What effect do the "dash 10's" hazardous materials have on the "dash 10's" transportability?	-	0 - 0	5	3 - 5	3	3 - 3
2.g	What effect does the "dash 10's" size have on the "dash 10's" transportability?	-	0 - 0	5	3 - 5	3	3 - 3

2.h	What effect does the "dash 10's" single-axle design have on the "dash 10's" transportability?	-	0 - 0	3	2 - 3	2	2 - 3
2.i	How much disassembly is required to prepare the "dash 10" for transport?	-	0 - 0	5	5 - 5	-	0 - 0
2.j	What effect does the "dash 10's" amount of disassembly (or lack thereof) have on the "dash 10's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0
3.a	How difficult is the TTU-228 hydraulic test stand ("mule") to prepare for deployment?	2	1 - 2	1	1 - 3	1	1 - 3
3.b	How difficult is the "mule" to reconstitute (prepare for use) after deployment?	3	2 - 3	2	2 - 3	2	2 - 3
3.c	What effect does the "mule's" ability to be palletized have on the "mule's" transportability?	-	0 - 0	1	1 - 3	3	3 - 3
3.d	What effect does the "mule's" lack of ability to be forklifted have on the "mule's" transportability?	-	0 - 0	1	1 - 2	1	1 - 2
3.e	What effect does the "mule's" size have on the "mule's" transportability?	-	0 - 0	2	2 - 2	-	0 - 0
3.f	What effect do the "mule's" hydraulic fluids have on the "mule's" transportability?	-	0 - 0	2	2 - 2	-	0 - 0
3.g	What effect does the "mule's" weight have on the "mule's" transportability?	-	0 - 0	2	2 - 2	-	0 - 0
3.h	How much disassembly is required to prepare the "mule" for transport?	-	0 - 0	2	2 - 4	3	3 - 4
3.i	What effect does the "mule's" amount of disassembly (or lack thereof) have on the "mule's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0
4.a	How difficult is the NF2-D external lighting cart ("light all") to prepare for deployment?	3	3 - 3	4	3 - 4	3	3 - 3
4.b	How difficult is the NF2-D ("light all") to reconstitute (prepare for use) after deployment?	3	3 - 4	4	3 - 4	3	3 - 3
4.c	What effect does the "light all's" ability to be palletized have on the "light all's" transportability?	-	0 - 0	4	3 - 4	3	3 - 3
4.d	What effect does the "light all's" ability to be forklifted have on the "light all's" transportability?	-	0 - 0	4	4 - 5	4	4 - 4
4.e	What effect does the "light all's" ground clearance have on the "light all's" transportability?	-	0 - 0	3	3 - 4	3	3 - 4
4.f	What effect does the "light all's" large size have on the "light all's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0

4.g	How much disassembly is required to prepare the "light all" for transport?						
	-	0 - 0	4	3 - 4	4	3 - 4	
4.h	What effect does the "light all's" amount of disassembly (or lack thereof) have on the "light all's" transportability?						
	-	0 - 0	4	3 - 4	4	3 - 4	

Analysis by Participant, Moody AGE Technician

Question	Round 0	Range	Round 1	Range	Round 2	Range
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to prepare for deployment?	2	2 - 3	2	2 - 3	2	2 - 3
1.b How difficult is the "dash 60" to reconstitute (prepare for use) after deployment?	2	2 - 4	3	3 - 4	3	3 - 3
1.c What effect does the "dash 60's" ability to be forklifted have on the "dash 60's" transportability?	-	0 - 0	-	5 - 5	-	0 - 0
1.d What effect does the "dash 60's" ability to be palletized have on the "dash 60's" transportability?	-	0 - 0	-	4 - 5	-	3 - 4
1.e What effect does the "dash 60's" lack of sling points have on the "dash 60's" transportability?	-	0 - 0	-	2 - 3	-	3 - 3
1.f What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?	-	0 - 0	4	3 - 4	4	3 - 4
1.g What effect does the "dash 60's" size have on the "dash 60's" transportability?	-	0 - 0	-	3 - 3	-	0 - 0
1.h What effect does the "dash 60's" fuel system have on the "dash 60's" transportability?	-	0 - 0	4	3 - 4	3	3 - 3
1.i How much disassembly is required to prepare the "dash 60" for transport?	-	0 - 0	3	3 - 4	3	3 - 4
1.j What effect does the "dash 60's" amount of disassembly (or lack thereof) have on the "dash 60's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to prepare for deployment?	3	3 - 5	3	3 - 5	3	3 - 5
2.b How difficult is the "dash 10" to reconstitute (prepare for use) after deployment?	3	3 - 5	4	3 - 5	3	3 - 5
2.c What effect does the "dash 10's" ability to be palletized have on the "dash 10's" transportability?	-	0 - 0	-	3 - 4	-	3 - 3
2.d What effect does the "dash 10's" lack of ability to be forklifted have on the "dash 10's" transportability?	-	0 - 0	-	2 - 2	-	0 - 0
2.e What effect does the "dash 10's" sling points have on the "dash 10's" transportability?	-	0 - 0	-	3 - 4	-	3 - 3
2.f What effect do the "dash 10's" hazardous materials have on the "dash 10's" transportability?	-	0 - 0	-	3 - 5	3	3 - 3
2.g What effect does the "dash 10's" size have on the "dash 10's" transportability?	-	0 - 0	-	3 - 5	-	3 - 3

2.h	What effect does the "dash 10's" single-axle design have on the "dash 10's" transportability?	-	0 - 0	-	2 - 3	-	2 - 3
2.i	How much disassembly is required to prepare the "dash 10" for transport?	-	0 - 0	5	5 - 5	-	0 - 0
2.j	What effect does the "dash 10's" amount of disassembly (or lack thereof) have on the "dash 10's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0
3.a	How difficult is the TTU-228 hydraulic test stand ("mule") to prepare for deployment?	1	1 - 2	1	1 - 3	1	1 - 3
3.b	How difficult is the "mule" to reconstitute (prepare for use) after deployment?	2	2 - 3	2	2 - 3	3	2 - 3
3.c	What effect does the "mule's" ability to be palletized have on the "mule's" transportability?	-	0 - 0	-	1 - 3	-	3 - 3
3.d	What effect does the "mule's" lack of ability to be forklifted have on the "mule's" transportability?	-	0 - 0	-	1 - 2	-	1 - 2
3.e	What effect does the "mule's" size have on the "mule's" transportability?	-	0 - 0	-	2 - 2	-	0 - 0
3.f	What effect do the "mule's" hydraulic fluids have on the "mule's" transportability?	-	0 - 0	2	2 - 2	-	0 - 0
3.g	What effect does the "mule's" weight have on the "mule's" transportability?	-	0 - 0	-	2 - 2	-	0 - 0
3.h	How much disassembly is required to prepare the "mule" for transport?	-	0 - 0	3	2 - 4	3	3 - 4
3.i	What effect does the "mule's" amount of disassembly (or lack thereof) have on the "mule's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0
4.a	How difficult is the NF2-D external lighting cart ("light all") to prepare for deployment?	3	3 - 3	3	3 - 4	3	3 - 3
4.b	How difficult is the NF2-D ("light all") to reconstitute (prepare for use) after deployment?	3	3 - 4	3	3 - 4	3	3 - 3
4.c	What effect does the "light all's" ability to be palletized have on the "light all's" transportability?	-	0 - 0	-	3 - 4	-	3 - 3
4.d	What effect does the "light all's" ability to be forklifted have on the "light all's" transportability?	-	0 - 0	-	4 - 5	-	4 - 4
4.e	What effect does the "light all's" ground clearance have on the "light all's" transportability?	-	0 - 0	4	3 - 4	4	3 - 4
4.f	What effect does the "light all's" large size have on the "light all's" transportability?	-	0 - 0	-	3 - 3	-	0 - 0

4.g	How much disassembly is required to prepare the "light all" for transport?						
	-	0 - 0	3	3 - 4	3	3 - 4	
4.h	What effect does the "light all's" amount of disassembly (or lack thereof) have on the "light all's" transportability?						
	-	0 - 0	4	3 - 4	-	3 - 4	

Analysis by Participant, Pope AGE Technician

Question	Round 0	Range	Round 1	Range	Round 2	Range
1.a	How difficult is the AM32A-60A turbine powered generator ("dash 60") to prepare for deployment?					
	3	2 - 3	3	2 - 3	3	2 - 3
1.b	How difficult is the "dash 60" to reconstitute (prepare for use) after deployment?					
	4	2 - 4	4	3 - 4	3	3 - 3
1.c	What effect does the "dash 60's" ability to be forklifted have on the "dash 60's" transportability?					
	-	0 - 0	5	5 - 5	-	0 - 0
1.d	What effect does the "dash 60's" ability to be palletized have on the "dash 60's" transportability?					
	-	0 - 0	4	4 - 5	4	3 - 4
1.e	What effect does the "dash 60's" lack of sling points have on the "dash 60's" transportability?					
	-	0 - 0	2	2 - 3	3	3 - 3
1.f	What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?					
	-	0 - 0	4	3 - 4	3	3 - 4
1.g	What effect does the "dash 60's" size have on the "dash 60's" transportability?					
	-	0 - 0	3	3 - 3	-	0 - 0
1.h	What effect does the "dash 60's" fuel system have on the "dash 60's" transportability?					
	-	0 - 0	3	3 - 4	3	3 - 3
1.i	How much disassembly is required to prepare the "dash 60" for transport?					
	-	0 - 0	4	3 - 4	4	3 - 4
1.j	What effect does the "dash 60's" amount of disassembly (or lack thereof) have on the "dash 60's" transportability?					
	-	0 - 0	3	3 - 3	-	0 - 0
2.a	How difficult is the AM32C-10 air conditioner ("dash 10") to prepare for deployment?					
	5	3 - 5	5	3 - 5	5	3 - 5
2.b	How difficult is the "dash 10" to reconstitute (prepare for use) after deployment?					
	5	3 - 5	5	3 - 5	5	3 - 5
2.c	What effect does the "dash 10's" ability to be palletized have on the "dash 10's" transportability?					
	-	0 - 0	4	3 - 4	3	3 - 3
2.d	What effect does the "dash 10's" lack of ability to be forklifted have on the "dash 10's" transportability?					
	-	0 - 0	2	2 - 2	-	0 - 0
2.e	What effect does the "dash 10's" sling points have on the "dash 10's" transportability?					
	-	0 - 0	4	3 - 4	3	3 - 3
2.f	What effect do the "dash 10's" hazardous materials have on the "dash 10's" transportability?					
	-	0 - 0	5	3 - 5	3	3 - 3
2.g	What effect does the "dash 10's" size have on the "dash 10's" transportability?					
	-	0 - 0	5	3 - 5	3	3 - 3

2.h	What effect does the "dash 10's" single-axle design have on the "dash 10's" transportability?						
		-	0 - 0	3	2 - 3	2	2 - 3
2.i	How much disassembly is required to prepare the "dash 10" for transport?						
		-	0 - 0	5	5 - 5	-	0 - 0
2.j	What effect does the "dash 10's" amount of disassembly (or lack thereof) have on the "dash 10's" transportability?						
		-	0 - 0	3	3 - 3	-	0 - 0
3.a	How difficult is the TTU-228 hydraulic test stand ("mule") to prepare for deployment?						
		2	1 - 2	1	1 - 3	1	1 - 3
3.b	How difficult is the "mule" to reconstitute (prepare for use) after deployment?						
		3	2 - 3	2	2 - 3	2	2 - 3
3.c	What effect does the "mule's" ability to be palletized have on the "mule's" transportability?						
		-	0 - 0	1	1 - 3	3	3 - 3
3.d	What effect does the "mule's" lack of ability to be forklifted have on the "mule's" transportability?						
		-	0 - 0	1	1 - 2	1	1 - 2
3.e	What effect does the "mule's" size have on the "mule's" transportability?						
		-	0 - 0	2	2 - 2	-	0 - 0
3.f	What effect do the "mule's" hydraulic fluids have on the "mule's" transportability?						
		-	0 - 0	2	2 - 2	-	0 - 0
3.g	What effect does the "mule's" weight have on the "mule's" transportability?						
		-	0 - 0	2	2 - 2	-	0 - 0
3.h	How much disassembly is required to prepare the "mule" for transport?						
		-	0 - 0	2	2 - 4	3	3 - 4
3.i	What effect does the "mule's" amount of disassembly (or lack thereof) have on the "mule's" transportability?						
		-	0 - 0	3	3 - 3	-	0 - 0
4.a	How difficult is the NF2-D external lighting cart ("light all") to prepare for deployment?						
		3	3 - 3	4	3 - 4	3	3 - 3
4.b	How difficult is the NF2-D ("light all") to reconstitute (prepare for use) after deployment?						
		3	3 - 4	4	3 - 4	3	3 - 3
4.c	What effect does the "light all's" ability to be palletized have on the "light all's" transportability?						
		-	0 - 0	4	3 - 4	3	3 - 3
4.d	What effect does the "light all's" ability to be forklifted have on the "light all's" transportability?						
		-	0 - 0	4	4 - 5	4	4 - 4
4.e	What effect does the "light all's" ground clearance have on the "light all's" transportability?						
		-	0 - 0	3	3 - 4	3	3 - 4
4.f	What effect does the "light all's" large size have on the "light all's" transportability?						
		-	0 - 0	3	3 - 3	-	0 - 0
4.g	How much disassembly is required to prepare the "light all" for						

	transport?							
	-	0 - 0	4	3 - 4	4	3	- 4	
4.h	What effect does the "light all's" amount of disassembly (or lack thereof) have on the "light all's" transportability?							
	-	0 - 0	4	3 - 4	4	3	- 4	

Appendix B. Data Analysis: Load Master and Boom Operator Questionnaires

Analysis by Question, Load Masters and Boom Operators

Question	McGuire (Boom)	Travis (Boom)	Dover (Load)	Travis (Load)	Range	Mean
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?						
Round 0	4	3	5	5	3 - 5	4.25
Round 1	4	3	5	4	3 - 5	4.00
Round 2	3	4	4	5	3 - 5	4.00
1.b How difficult is the "dash 60" to load on an aircraft?						
Round 0	4	3	5	4	3 - 5	4.00
Round 1	3	4	5	4	3 - 5	4.00
Round 2	3	4	4	5	3 - 5	4.00
1.c What effect does the "dash 60" pallet overhang have on the "dash 60's" transportability?						
Round 0	-	-	-	-	0 - 0	0.00
Round 1	2	2	3	-	2 - 3	2.33
Round 2	2	2	3	3	2 - 3	2.50
1.d What effect does the "dash 60s" rolling stock characteristics (roll-on/roll-off) have on the "dash 60's" transportability?						
Round 0	-	-	-	-	0 - 0	0.00
Round 1	3	3	5	5	3 - 5	4.00
Round 2	3	3	4	4	3 - 4	3.50
1.e What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?						
Round 0	-	-	-	-	0 - 0	0.00
Round 1	3	3	4	5	3 - 5	3.75
Round 2	3	3	4	4	3 - 4	3.50
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?						
Round 0	3	2	4	3	2 - 4	3.00
Round 1	3	2	3	3	2 - 3	2.75
Round 2	3	2	3	4	2 - 4	3.00
2.b How difficult is the "dash 10" to load on an aircraft?						
Round 0	3	3	4	3	3 - 4	3.25
Round 1	3	3	4	3	3 - 4	3.25
Round 2	3	3	3	4	3 - 4	3.25
2.c What effect does the "dash 10's" single axle design have on the "dash 10's" transportability?						
Round 0	-	-	-	-	0 - 0	0.00
Round 1	3	3	2	2	2 - 3	2.50
Round 2	3	3	3	3	3 - 3	3.00
2.d What effect does the "dash 10's" size and weight have on the "dash 10's" transportability?						
Round 0	-	-	-	-	0 - 0	0.00
Round 1	3	2	3	2	2 - 3	2.50
Round 2	3	3	3	3	3 - 3	3.00

2.e	What effect does the "dash 10s" rolling stock characteristics (roll-on/roll-off) have on the "dash 10's" transportability?				
Round 0	-	-	-	-	0 - 0 0.00
Round 1	4	3	4	2	2 - 4 3.25
Round 2	3	3	3	3	$\boxed{3 - 3\ 3.00}$
3.a	How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?				
Round 0	3	3	3	3	3 - 3 3.00
Round 1	3	3	3	3	$\boxed{3 - 3\ 3.00}$
Round 2	-	-	-	-	0 - 0 0.00
3.b	How difficult is the "mule" to load on an aircraft?				
Round 0	3	3	3	3	3 - 3 3.00
Round 1	3	3	3	3	$\boxed{3 - 3\ 3.00}$
Round 2	-	-	-	-	0 - 0 0.00
3.c	What effect does the "mule's" weight have on the "mule's" transportability?				
Round 0	-	-	-	-	0 - 0 0.00
Round 1	2	3	3	3	2 - 3 2.75
Round 2	3	3	3	3	$\boxed{3 - 3\ 3.00}$
3.d	What effect does the "mule's" rolling stock characteristics (roll-on/roll-off) have on the "mule's" transportability?				
Round 0	-	-	-	-	0 - 0 0.00
Round 1	3	3	3	4	3 - 4 3.25
Round 2	4	3	4	4	3 - 4 3.75
4.a	How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?				
Round 0	3	5	5	5	3 - 5 4.50
Round 1	3	5	5	5	3 - 5 4.50
Round 2	5	5	5	5	$\boxed{5 - 5\ 5.00}$
4.b	How difficult is the "light all" to load on an aircraft?				
Round 0	3	5	5	5	3 - 5 4.50
Round 1	3	5	5	5	3 - 5 4.50
Round 2	3	4	5	5	3 - 5 4.25
4.c	What effect does the "light all's" weight have on the "light all's" transportability?				
Round 0	-	-	-	-	0 - 0 0.00
Round 1	3	3	3	3	$\boxed{3 - 3\ 3.00}$
Round 2	-	-	-	-	0 - 0 0.00
4.d	What effect does the "light all's" ground clearance have on the "light all's" transportability?				
Round 0	-	-	-	-	0 - 0 0.00
Round 1	3	3	4	4	3 - 4 3.50
Round 2	3	3	4	3	3 - 4 3.25
4.e	What effect does the "light all's" rolling stock characteristics (roll-on/roll-off) have on the "light all's" transportability?				
Round 0	-	-	-	-	0 - 0 0.00
Round 1	4	3	4	4	3 - 4 3.75
Round 2	3	3	4	4	3 - 4 3.50

Where consensus was reached the results are boxed.

Analysis by Participant, McGuire Boom Operator

Question	Round 0	Range	Round 1	Range	Round 2	Range
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?	4	3 - 5	3	3 - 5	3	3 - 5
1.b How difficult is the "dash 60" to load on an aircraft?	4	3 - 5	3	3 - 5	3	3 - 5
1.c What effect does the "dash 60" pallet overhang have on the "dash 60's" transportability?	-	0 - 0	2	2 - 3	2	2 - 3
1.d What effect does the "dash 60s" rolling stock characteristics (roll-on/roll-off) have on the "dash 60's" transportability?	-	0 - 0	3	3 - 5	3	3 - 4
1.e What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?	-	0 - 0	3	3 - 5	3	3 - 4
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?	3	2 - 4	3	2 - 3	3	2 - 4
2.b How difficult is the "dash 10" to load on an aircraft?	3	3 - 4	3	3 - 4	3	3 - 4
2.c What effect does the "dash 10's" single axle design have on the "dash 10's" transportability?	-	0 - 0	3	2 - 3	3	3 - 3
2.d What effect does the "dash 10's" size and weight have on the "dash 10's" transportability?	-	0 - 0	3	2 - 3	3	3 - 3
2.e What effect does the "dash 10s" rolling stock characteristics (roll-on/roll-off) have on the "dash 10's" transportability?	-	0 - 0	4	2 - 4	3	3 - 3
3.a How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?	3	3 - 3	3	3 - 3	-	0 - 0
3.b How difficult is the "mule" to load on an aircraft?	3	3 - 3	3	3 - 3	-	0 - 0
3.c What effect does the "mule's" weight have on the "mule's" transportability?	-	0 - 0	2	2 - 3	3	3 - 3
3.d What effect does the "mule's" rolling stock characteristics (roll-on/roll-off) have on the "mule's" transportability?	-	0 - 0	3	3 - 4	4	3 - 4
4.a How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?	3	3 - 5	3	3 - 5	5	5 - 5
4.b How difficult is the "light all" to load on an aircraft?	3	3 - 5	3	3 - 5	3	3 - 5
4.c What effect does the "light all's" weight have on the "light all's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0

4.d	What effect does the "light all's" ground clearance have on the "light all's" transportability?						
	-	0 - 0	3	3 - 4	3	3 - 4	
4.e	What effect does the "light all's" rolling stock characteristics (roll-on/roll-off) have on the "light all's" transportability?						
	-	0 - 0	4	3 - 4	3	3 - 4	

Analysis by Participant, Travis Boom Operator

Question	Round 0	Range	Round 1	Range	Round 2	Range
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?	3	3 - 5	4	3 - 5	3	3 - 5
1.b How difficult is the "dash 60" to load on an aircraft?	3	3 - 5	4	3 - 5	4	3 - 5
1.c What effect does the "dash 60" pallet overhang have on the "dash 60's" transportability?	-	0 - 0	2	2 - 3	2	2 - 3
1.d What effect does the "dash 60s" rolling stock characteristics (roll-on/roll-off) have on the "dash 60's" transportability?	-	0 - 0	3	3 - 5	3	3 - 4
1.e What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?	-	0 - 0	3	3 - 5	3	3 - 4
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?	2	2 - 4	2	2 - 3	2	2 - 4
2.b How difficult is the "dash 10" to load on an aircraft?	3	3 - 4	3	3 - 4	3	3 - 4
2.c What effect does the "dash 10's" single axle design have on the "dash 10's" transportability?	-	0 - 0	3	2 - 3	3	3 - 3
2.d What effect does the "dash 10's" size and weight have on the "dash 10's" transportability?	-	0 - 0	2	2 - 3	3	3 - 3
2.e What effect does the "dash 10s" rolling stock characteristics (roll-on/roll-off) have on the "dash 10's" transportability?	-	0 - 0	3	2 - 4	3	3 - 3
3.a How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?	3	3 - 3	3	3 - 3	-	0 - 0
3.b How difficult is the "mule" to load on an aircraft?	3	3 - 3	3	3 - 3	-	0 - 0
3.c What effect does the "mule's" weight have on the "mule's" transportability?	-	0 - 0	3	2 - 3	3	3 - 3
3.d What effect does the "mule's" rolling stock characteristics (roll-on/roll-off) have on the "mule's" transportability?	-	0 - 0	3	3 - 4	3	3 - 4
4.a How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?	5	3 - 5	5	3 - 5	5	5 - 5
4.b How difficult is the "light all" to load on an aircraft?	5	3 - 5	5	3 - 5	4	3 - 5
4.c What effect does the "light all's" weight have on the "light all's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0

4.d	What effect does the "light all's" ground clearance have on the "light all's" transportability?						
	-	0 - 0	3	3 - 4	3	3 - 4	
4.e	What effect does the "light all's" rolling stock characteristics (roll-on/roll-off) have on the "light all's" transportability?						
	-	0 - 0	3	3 - 4	3	3 - 4	

Analysis by Participant, Dover Load Master

Question	Round 0	Range	Round 1	Range	Round 2	Range
1.a	How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?					
	5	3 - 5	4	3 - 5	4	3 - 5
1.b	How difficult is the "dash 60" to load on an aircraft?					
	5	3 - 5	5	3 - 5	4	3 - 5
1.c	What effect does the "dash 60" pallet overhang have on the "dash 60's" transportability?					
	-	0 - 0	3	2 - 3	3	2 - 3
1.d	What effect does the "dash 60s" rolling stock characteristics (roll-on/roll-off) have on the "dash 60's" transportability?					
	-	0 - 0	5	3 - 5	4	3 - 4
1.e	What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?					
	-	0 - 0	4	3 - 5	4	3 - 4
2.a	How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?					
	4	2 - 4	3	2 - 3	3	2 - 4
2.b	How difficult is the "dash 10" to load on an aircraft?					
	4	3 - 4	4	3 - 4	3	3 - 4
2.c	What effect does the "dash 10's" single axle design have on the "dash 10's" transportability?					
	-	0 - 0	2	2 - 3	3	3 - 3
2.d	What effect does the "dash 10's" size and weight have on the "dash 10's" transportability?					
	-	0 - 0	3	2 - 3	3	3 - 3
2.e	What effect does the "dash 10s" rolling stock characteristics (roll-on/roll-off) have on the "dash 10's" transportability?					
	-	0 - 0	4	2 - 4	3	3 - 3
3.a	How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?					
	3	3 - 3	3	3 - 3	-	0 - 0
3.b	How difficult is the "mule" to load on an aircraft?					
	3	3 - 3	3	3 - 3	-	0 - 0
3.c	What effect does the "mule's" weight have on the "mule's" transportability?					
	-	0 - 0	3	2 - 3	3	3 - 3
3.d	What effect does the "mule's" rolling stock characteristics (roll-on/roll-off) have on the "mule's" transportability?					
	-	0 - 0	3	3 - 4	4	3 - 4
4.a	How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?					
	5	3 - 5	5	3 - 5	5	5 - 5
4.b	How difficult is the "light all" to load on an aircraft?					
	5	3 - 5	5	3 - 5	5	3 - 5
4.c	What effect does the "light all's" weight have on the "light all's" transportability?					
	-	0 - 0	3	3 - 3	-	0 - 0

4.d	What effect does the "light all's" ground clearance have on the "light all's" transportability?						
	-	0 - 0	4	3 - 4	4	3 - 4	
4.e	What effect does the "light all's" rolling stock characteristics (roll-on/roll-off) have on the "light all's" transportability?						
	-	0 - 0	4	3 - 4	4	3 - 4	

Analysis by Participant, Travis Load Master

Question	Round 0	Range	Round 1	Range	Round 2	Range
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?	5	3 - 5	5	3 - 5	5	3 - 5
1.b How difficult is the "dash 60" to load on an aircraft?	4	3 - 5	4	3 - 5	5	3 - 5
1.c What effect does the "dash 60" pallet overhang have on the "dash 60's" transportability?	-	0 - 0	-	2 - 3	3	2 - 3
1.d What effect does the "dash 60s" rolling stock characteristics (roll-on/roll-off) have on the "dash 60's" transportability?	-	0 - 0	5	3 - 5	4	3 - 4
1.e What effect does the "dash 60's" ground clearance have on the "dash 60's" transportability?	-	0 - 0	5	3 - 5	4	3 - 4
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?	3	2 - 4	3	2 - 3	4	2 - 4
2.b How difficult is the "dash 10" to load on an aircraft?	3	3 - 4	3	3 - 4	4	3 - 4
2.c What effect does the "dash 10's" single axle design have on the "dash 10's" transportability?	-	0 - 0	2	2 - 3	3	3 - 3
2.d What effect does the "dash 10's" size and weight have on the "dash 10's" transportability?	-	0 - 0	2	2 - 3	3	3 - 3
2.e What effect does the "dash 10s" rolling stock characteristics (roll-on/roll-off) have on the "dash 10's" transportability?	-	0 - 0	2	2 - 4	3	3 - 3
3.a How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?	3	3 - 3	3	3 - 3	-	0 - 0
3.b How difficult is the "mule" to load on an aircraft?	3	3 - 3	3	3 - 3	-	0 - 0
3.c What effect does the "mule's" weight have on the "mule's" transportability?	-	0 - 0	3	2 - 3	3	3 - 3
3.d What effect does the "mule's" rolling stock characteristics (roll-on/roll-off) have on the "mule's" transportability?	-	0 - 0	4	3 - 4	4	3 - 4
4.a How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?	5	3 - 5	5	3 - 5	5	5 - 5
4.b How difficult is the "light all" to load on an aircraft?	5	3 - 5	5	3 - 5	5	3 - 5
4.c What effect does the "light all's" weight have on the "light all's" transportability?	-	0 - 0	3	3 - 3	-	0 - 0

4.d	What effect does the "light all's" ground clearance have on the "light all's" transportability?						
	-	0 - 0	4	3 - 4	3	3 - 4	
4.e	What effect does the "light all's" rolling stock characteristics (roll-on/roll-off) have on the "light all's" transportability?						
	-	0 - 0	4	3 - 4	4	3 - 4	

Appendix C. Data Analysis: Logistics Planner Questionnaires

Analysis by Question, Logistics Planners

Question	Cannon	Moody	Pope	Range	Mean
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?					
Round 0	4	4	3	3 - 4	3.67
Round 1	5	3	3	3 - 5	3.67
Round 2	5	3	3	3 - 5	3.67
1.b How difficult is the "dash 60" to martial between cargo holding points?					
Round 0	4	4	3	3 - 4	3.67
Round 1	4	3	3	3 - 4	3.33
Round 2	4	2	3	2 - 4	3.00
1.c How difficult is the "dash 60" to prepare for transportation?					
Round 0	4	-	3	3 - 4	3.50
Round 1	-	3	3	3 - 3	3.00
Round 2	-	-	-	0 - 0	0.00
1.d What effect does the "dash 60's" fuel system (its large fuel capacity) have on the "dash 60's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	3	2	2 - 3	2.67
Round 2	3	3	2	2 - 3	2.67
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?					
Round 0	5	4	3	3 - 5	4.00
Round 1	5	3	3	3 - 5	3.67
Round 2	5	3	3	3 - 5	3.67
2.b How difficult is the "dash 10" to martial between cargo holding points?					
Round 0	4	4	3	3 - 4	3.67
Round 1	4	3	3	3 - 4	3.33
Round 2	4	2	3	2 - 4	3.00
2.c How difficult is the "dash 10" to prepare for transportation?					
Round 0	4	-	5	4 - 5	4.50
Round 1	-	3	5	3 - 5	4.00
Round 2	-	3	5	3 - 5	4.00
2.d What effect does the "dash 10's" lack of an internal engine have on the "dash 10's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	5	3	5	3 - 5	4.33
Round 2	5	4	5	4 - 5	4.67
3.a How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?					
Round 0	4	3	3	3 - 4	3.33
Round 1	5	3	3	3 - 5	3.67
Round 2	-	3	3	3 - 3	3.00

3.b How difficult is the "mule" to martial between cargo holding points?					
Round 0	4	4	3	3 - 4	3.67
Round 1	4	3	3	3 - 4	3.33
Round 2	5	2	3	2 - 5	3.33
3.c How difficult is the "mule" to prepare for transportation?					
Round 0	4	-	2	2 - 4	3.00
Round 1	-	2	2	$\boxed{2 - 2}$	$\boxed{2.00}$
Round 2	-	-	-	0 - 0	0.00
3.d What effect does the "mule's" large size have on the "mule's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	3	2	2 - 3	2.67
Round 2	3	3	2	2 - 3	2.67
3.e What effect does the "mule's" hydraulic system have on the "mule's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	3	2	2 - 3	2.67
Round 2	3	3	2	2 - 3	2.67
4.a How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?					
Round 0	5	5	3	3 - 5	4.33
Round 1	5	4	3	3 - 5	4.00
Round 2	5	3	3	3 - 5	3.67
4.b How difficult is the "light all" to martial between cargo holding points?					
Round 0	5	5	3	3 - 5	4.33
Round 1	5	3	3	3 - 5	3.67
Round 2	5	3	3	3 - 5	3.67
4.c How difficult is the NF2-D ("light all") to prepare for transportation?					
Round 0	5	-	3	3 - 5	4.00
Round 1	-	3	3	$\boxed{3 - 3}$	$\boxed{3.00}$
Round 2	-	-	-	0 - 0	0.00
4.d What effect does the "light all's" simple internal combustion engine have on the "light all's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	4	3	3	3 - 4	3.33
Round 2	4	2	3	2 - 4	3.00
4.e What effect does the "light all's" small fuel tank have on the "light all's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	3	4	3 - 4	3.33
Round 2	3	3	4	3 - 4	3.33
4.f What effect do the "light all's" large flood lights have on the "light all's" transportability?					
Round 0	-	-	-	0 - 0	0.00
Round 1	3	3	2	2 - 3	2.67
Round 2	3	3	2	2 - 3	2.67

Where consensus was reached the results are boxed.

Analysis by Participant, Cannon Logistics Planner

Question		Round 0	Range	Round 1	Range	Round 2	Range
1.a	How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?	4	3 - 4	5	3 - 5	5	3 - 5
1.b	How difficult is the "dash 60" to martial between cargo holding points?	4	3 - 4	4	3 - 4	4	2 - 4
1.c	How difficult is the "dash 60" to prepare for transportation?	4	3 - 4	-	3 - 3	-	0 - 0
1.d	What effect does the "dash 60's" fuel system (its large fuel capacity) have on the "dash 60's" transportability?	-	0 - 0	3	2 - 3	3	2 - 3
2.a	How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?	5	3 - 5	5	3 - 5	5	3 - 5
2.b	How difficult is the "dash 10" to martial between cargo holding points?	4	3 - 4	4	3 - 4	4	2 - 4
2.c	How difficult is the "dash 10" to prepare for transportation?	4	4 - 5	-	3 - 5	-	3 - 5
2.d	What effect does the "dash 10's" lack of an internal engine have on the "dash 10's" transportability?	-	0 - 0	5	3 - 5	5	4 - 5
3.a	How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?	4	3 - 4	5	3 - 5	-	3 - 3
3.b	How difficult is the "mule" to martial between cargo holding points?	4	3 - 4	4	3 - 4	5	2 - 5
3.c	How difficult is the "mule" to prepare for transportation?	4	2 - 4	-	2 - 2	-	0 - 0
3.d	What effect does the "mule's" large size have on the "mule's" transportability?	-	0 - 0	3	2 - 3	3	2 - 3
3.e	What effect does the "mule's" hydraulic system have on the "mule's" transportability?	-	0 - 0	3	2 - 3	3	2 - 3
4.a	How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?	5	3 - 5	5	3 - 5	5	3 - 5
4.b	How difficult is the "light all" to martial between cargo holding points?	5	3 - 5	5	3 - 5	5	3 - 5
4.c	How difficult is the NF2-D ("light all") to prepare for transportation?	5	3 - 5	-	3 - 3	-	0 - 0
4.d	What effect does the "light all's" simple internal combustion engine have on the "light all's" transportability?	-	0 - 0	4	3 - 4	4	2 - 4

4.e	What effect does the "light all's" small fuel tank have on the "light all's" transportability?						
	-	0 - 0	3	3 - 4	3	3 - 4	
4.f	What effect do the "light all's" large flood lights have on the "light all's" transportability?						
	-	0 - 0	3	2 - 3	3	2 - 3	

Analysis by Participant, Moody Logistics Planner

Question	Round 0	Range	Round 1	Range	Round 2	Range
1.a How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?	4	3 - 4	3	3 - 5	3	3 - 5
1.b How difficult is the "dash 60" to martial between cargo holding points?	4	3 - 4	3	3 - 4	2	2 - 4
1.c How difficult is the "dash 60" to prepare for transportation?	-	3 - 4	3	3 - 3	-	0 - 0
1.d What effect does the "dash 60's" fuel system (its large fuel capacity) have on the "dash 60's" transportability?	-	0 - 0	3	2 - 3	3	2 - 3
2.a How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?	4	3 - 5	3	3 - 5	3	3 - 5
2.b How difficult is the "dash 10" to martial between cargo holding points?	4	3 - 4	3	3 - 4	2	2 - 4
2.c How difficult is the "dash 10" to prepare for transportation?	-	4 - 5	3	3 - 5	3	3 - 5
2.d What effect does the "dash 10's" lack of an internal engine have on the "dash 10's" transportability?	-	0 - 0	3	3 - 5	4	4 - 5
3.a How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?	3	3 - 4	3	3 - 5	3	3 - 3
3.b How difficult is the "mule" to martial between cargo holding points?	4	3 - 4	3	3 - 4	2	2 - 5
3.c How difficult is the "mule" to prepare for transportation?	-	2 - 4	2	2 - 2	-	0 - 0
3.d What effect does the "mule's" large size have on the "mule's" transportability?	-	0 - 0	3	2 - 3	3	2 - 3
3.e What effect does the "mule's" hydraulic system have on the "mule's" transportability?	-	0 - 0	3	2 - 3	3	2 - 3
4.a How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?	5	3 - 5	4	3 - 5	3	3 - 5
4.b How difficult is the "light all" to martial between cargo holding points?	5	3 - 5	3	3 - 5	3	3 - 5
4.c How difficult is the NF2-D ("light all") to prepare for transportation?	-	3 - 5	3	3 - 3	-	0 - 0
4.d What effect does the "light all's" simple internal combustion engine have on the "light all's" transportability?	-	0 - 0	3	3 - 4	2	2 - 4

4.e	What effect does the "light all's" small fuel tank have on the "light all's" transportability?						
	-	0 - 0	3	3 - 4	3	3 - 4	
4.f	What effect do the "light all's" large flood lights have on the "light all's" transportability?						
	-	0 - 0	3	2 - 3	3	2 - 3	

Analysis by Participant, Pope Logistics Planner

Question	Round 0	Range	Round 1	Range	Round 2	Range
1.a	How difficult is the AM32A-60A turbine powered generator ("dash 60") to incorporate into load plans?					
	4	3 - 4	5	3 - 5	5	3 - 5
1.b	How difficult is the "dash 60" to martial between cargo holding points?					
	4	3 - 4	4	3 - 4	4	2 - 4
1.c	How difficult is the "dash 60" to prepare for transportation?					
	4	3 - 4	-	3 - 3	-	0 - 0
1.d	What effect does the "dash 60's" fuel system (its large fuel capacity) have on the "dash 60's" transportability?					
	-	0 - 0	3	2 - 3	3	2 - 3
2.a	How difficult is the AM32C-10 air conditioner ("dash 10") to incorporate into load plans?					
	5	3 - 5	5	3 - 5	5	3 - 5
2.b	How difficult is the "dash 10" to martial between cargo holding points?					
	4	3 - 4	4	3 - 4	4	2 - 4
2.c	How difficult is the "dash 10" to prepare for transportation?					
	4	4 - 5	-	3 - 5	-	3 - 5
2.d	What effect does the "dash 10's" lack of an internal engine have on the "dash 10's" transportability?					
	-	0 - 0	5	3 - 5	5	4 - 5
3.a	How difficult is the TTU-228 hydraulic test stand ("mule") to incorporate into load plans?					
	4	3 - 4	5	3 - 5	-	3 - 3
3.b	How difficult is the "mule" to martial between cargo holding points?					
	4	3 - 4	4	3 - 4	5	2 - 5
3.c	How difficult is the "mule" to prepare for transportation?					
	4	2 - 4	-	2 - 2	-	0 - 0
3.d	What effect does the "mule's" large size have on the "mule's" transportability?					
	-	0 - 0	3	2 - 3	3	2 - 3
3.e	What effect does the "mule's" hydraulic system have on the "mule's" transportability?					
	-	0 - 0	3	2 - 3	3	2 - 3
4.a	How difficult is the NF2-D external lighting cart ("light all") to incorporate into load plans?					
	5	3 - 5	5	3 - 5	5	3 - 5
4.b	How difficult is the "light all" to martial between cargo holding points?					
	5	3 - 5	5	3 - 5	5	3 - 5
4.c	How difficult is the NF2-D ("light all") to prepare for transportation?					
	5	3 - 5	-	3 - 3	-	0 - 0
4.d	What effect does the "light all's" simple internal combustion engine have on the "light all's" transportability?					
	-	0 - 0	4	3 - 4	4	2 - 4

4.e	What effect does the "light all's" small fuel tank have on the "light all's" transportability?						
	-	0 - 0	3	3 - 4	3	3 - 4	
4.f	What effect do the "light all's" large flood lights have on the "light all's" transportability?						
	-	0 - 0	3	2 - 3	3	2 - 3	

References

Anderson, D. "Increased productivity via group decision making," *Supervision, 51*: 6-10 (September 1990).

Battelle Memorial Institute. "MASS Design Supportability Studies Subtask 4: AGE Maintainability," Battelle Final Technical Report. Columbus OH, July 11, 1996.

Battelle Memorial Institute. "Modular support equipment research - Modular AGE trade studies," Battelle Technical Report. Columbus OH, September 30, 1996.

Boyle, E. and M. Tracy. "Rethinking Support Equipment," *Air Force Journal of Logistics. XIX*, no. 4, 28-31.

Brown, B. *DELPHI PROCESS: A Methodology Used for the Elicitation of Opinions of Experts*. RAND Paper P-3925, Santa Monica CA: September 1968.

Brown, B. and O. Helmer. *Improving the Reliability of Estimates Obtained from a Consensus of Experts*. RAND Paper P-2986, Santa Monica CA: September 1964.

Congressional Budget Office (CBO). *Improving Strategic Mobility: The C-17 Program and Alternatives*. Washington, Government Printing Office: September 1986.

Congressional Budget Office (CBO). *Moving U.S. Forces: Options for Strategic Mobility*. Washington, Government Printing Office: February 1997.

Courtois, D. and D. Yockey. *A Delphi Study of Performance Appraisal Practices of Malcolm Baldrige Award Winning Organizations*. MS Thesis, AFIT/GLM/LAR/94S-9. Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1994 (AD-A 285041).

Cummins, C. *Intra-Theater Mobilization: Guidance, Process, and Tools*. MS Thesis, AFIT/GLM/LSM/92S-12. Graduate School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1992 (AD-A 259015).

Dalkey, N. *Delphi*. RAND Paper P-3704, Santa Monica CA: October 1967.

Department of the Air Force. "3FKM3 Unit Type Code (UTC)," Contingency Operations Mobility Planning and Execution System, Base-level Logistics Module. Gunter Annex, Maxwell AFB AL, December 1995.

Department of the Air Force. *Air Mobility Master Plan.* Scott AFB IL: HQ AMC/XP, 1997.

Department of the Air Force. "Agile Combat Support." WWWeb, http://www.af-future.hq.af.mil/21/coret/agit.htm (May 25th, 1997).

Department of the Air Force. "Global Engagement." WWWeb, http://www.af-future.hq.af.mil/21/indext.htm (May 25th, 1997).

Department of the Air Force. Minutes for the USAF Aircraft Ground Support Equipment Working Group (AGSEWG) Meeting, Oct 96.

Department of the Air Force. "Rapid Global Mobility." WWWeb, http://www.af-future.hq.af.mil/21/coret/rapt.htm (May 25th, 1997).

Department of the Army (Army Materiel Systems Analysis Activity). "Mobility as an Effectiveness Factor," *Weapon Systems Effectiveness Methodology, #12.* Aberdeen Proving Ground MD: 1984. (Video Taped Briefing)

Farquhar, M. *An Analysis of the Literature Base of Defense Contract Management.* MS Thesis, AFIT/GCM/LSP/89S-5. Graduate School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1989 (AD-A 216346).

Gaumer, T. "S[upport] E[quipment] Mobility Implications." Briefing given on 21 Aug 96 (53 slides).

Griffis, S. and J. Martin. *Development and Analysis of a Dual-Role Fighter Deployment Footprint Logistics Planning Equation.* MS Thesis, AFIT/GLM/LAP/96S-4. Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1996 (AD-A 319491).

Grove, M. and E. Upshaw. *Content of Air Force Institute of Technology Course CON 331 as Determined by Experts in the Field: A Contracting Survey Analysis Using the Delphi Technique.* MS Thesis, AFIT/GCM/LSQ/93S-7. Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1993 (AD-A 276280).

Helmer, O. and N. Rescher. *On the Epistemology of the Inexact Sciences.* RAND Paper R-353, Santa Monica CA: February 1960.

Joint Pub 3-17. *Joint Tactics, Techniques, and Procedures for Theater Airlift Operations.* Washington DC: Joint Chiefs of Staff Publication, 18 July 1995.

Kassing, D., K. Girardini, B. Leverich, R. Stanton, and R. Eden. *New Tools for Balancing Theater Combat and Support*. RAND Paper DB-150-A, Santa Monica CA: 1996.

Kee, R. *Bridging the Gulf Between Theater and Strategic Air Mobility*. MS Thesis, AFIT/GMO/LAL/96N-4. Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1996 (AD-A 320506).

Morton, C. *An Analysis of the Purchase Request Process at Wright Laboratories*. MS Thesis, AFIT/GCM/LSP/91S-10. Graduate School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1991 (AD-A 243927).

Pavek, Dwight X. Research Scientist, Logistics Research Division, Armstrong Laboratory, Wright-Patterson AFB OH. Personal Interview. 26 Aug 1997.

Perkins, S. *Global Demands: Limited Forces*. National Defense University Press, Fort Lesley J. McNair: Washington DC, 1984.

Schank, J., J. Tucker, M. Mattock, and J. Rothenberg. *New Capabilities for Strategic Mobility Analysis*. RAND Paper MR-294-JS, Santa Monica CA: 1994.

Sowell, L., Jr. *Base Development and the Rapid Deployment Force: A Window to the Future*. National Defense University Press: Fort Lesley J. McNair, Washington DC, 1982.

Susalla, M. Thermodynamic Improvements for the Space Thermoacoustic Refrigerator (STAR). MS Thesis. Physics, Naval Postgraduate School, Monterey CA, June 1988.

Tate, D. DEPLOY: *An Interactive Goal Programming Model for the Rapid Deployment of Armed Forces*. MS Thesis, AFIT/GOR/OS/84D-14. Graduate Operations Research, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1984 (AD-A 152007).

Tersine, R. and W. Riggs. "The Delphi Technique: A Long Range Planning Tool," *Business Horizons, 19*: 51-56 (April 1976).

Zeck, W., B. Lloyd, and R. Pool. "Enhanced Contingency Logistics Planning and Support Environment: Defining a Vision for Future Deployment Planning," *Air Force Journal of Logistics*, Fall 1995.

Zycher, B. and D. Morton. *Transportability in the Defense Department Research, Development, and Acquisition Process*. RAND Paper R-4107, Santa Monica CA: 1991.

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The issue of mobility is vital to the Air Force as it faces the 21st century. Operational units must be prepared to quickly deploy anywhere in the world. Aerospace Ground Equipment (AGE) is a large portion of any operational unit's mobility requirements. This thesis studies one portion of AGE mobility, the transportability characteristics of the Air Force's current powered AGE. Transportability is defined as the ability to quickly and efficiently prepare an item for transport, load the item on the transportation asset, remove the item from the transportation asset, and reconstitute the item for use.

In order to determine AGE transportability characteristics, a Delphi study was conducted to solicit inputs from experts in the field. Study participants were three AGE technicians and three logistics planners from three fighter wings and two C-5 load masters and two KC-10 boom operators from three mobility wings. Factors that improved the transportability of AGE were the ability to be lifted by forklift, the ability to be rolled-on and rolled-off of transport aircraft, and high ground clearance. Factors that hindered mobility were large fuel capacities, large size (especially if pallet overhang occurred), heavy weight, and single axle designs.

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